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Naval Surface Warfare Center
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Center for Innovation in Ship Design

Technical Report

Hospital Ship Replacement

By

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14. ABSTRACT
The Center for Innovation in Ship Design (CISD) requested the development of a concept that could serve as a replacement for the existing hospital ships. The U.S. Navy plays a significant role in humanitarian missions by providing immediate aid during disaster situations. The existing hospital ships, USNS *Mercy* (T-AHS 19) and USNS *Comfort* (T-AHS 20) carry out two missions: 1) to provide medical and surgical care in support of U.S. amphibious task forces, and 2) to serve as a full-service hospital for use by various government agencies involved in support of non-combat roles such as disaster relief and humanitarian assistance. These hospital ships are over 35 years old and will need to be replaced once they are at the end of their service life. Other shortcomings include excessive draft, seakeeping at zero knots, low-speed maneuverability and inadequate patient throughput. The Navy Bureau of Medicine has stressed the need for modular medical facilities and amphibious support to enable increased ship-to-shore patient transfer and extend medical capabilities ashore.

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Abstract

The Center for Innovation in Ship Design (CISD) requested the development of a concept that could serve as a replacement for the existing hospital ships. The U.S. Navy plays a significant role in humanitarian missions by providing immediate aid during disaster situations. The existing hospital ships, USNS *Mercy* (T-AHS 19) and USNS *Comfort* (T-AHS 20) carry out two missions: 1) to provide medical and surgical care in support of U.S. amphibious task forces, and 2) to serve as a full-service hospital for use by various government agencies involved in support of non-combat roles such as disaster relief and humanitarian assistance. These hospital ships are over 35 years old and will need to be replaced once they are at the end of their service life. Other shortcomings include excessive draft, seakeeping at zero knots, low-speed maneuverability, and inadequate patient throughput. The Navy Bureau of Medicine has stressed the need for modular medical facilities and amphibious support to enable increased ship-to-shore patient transfer and extend medical capabilities ashore.

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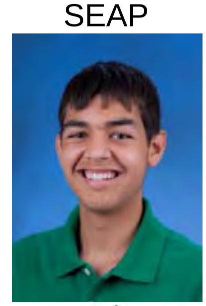

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Acronyms

ABS	American Bureau of Shipping
AFM	Army Field Manual
BUMED	Navy Bureau of Medicine and Surgery
CBRNE	Chemical, Biological, Radiological, Nuclear, Explosive
CISD	Center for Innovation in Ship Design
EPA	Environmental Protection Agency
HA/DR	Humanitarian Aid/ Disaster Relief
HCA	Humanitarian Civic Assistance
HSR	Hospital Ship Replacement
ICU	Intensive Care Unit
IMO	International Maritime Organization
LBP	Length Between Perpendiculars
LCAC	Landing Craft Air Cushion
LOA	Length Overall
LPD	Landing Platform Dock
MARPOL	Marine Pollution
MSC	Military Sealift Command
NAVSEA	Naval Sea Systems Command
NREIP	Naval Research Enterprise Intern Program
ROC/POE	Required Operational Capability and Projected Operational Environment
SAIC	Science Applications International Corporation
SEAP	Science and Engineering Apprenticeship Program
SOLAS	Safety of Life at Sea
SWBS	Ship Weight Breakdown Structure
USNS	United States Naval Ship

1.0 Introduction

1.1 Objective

The goal of this design is to create a ship concept to replace the U.S. Navy's existing hospital ships. The ship design incorporates mission requirements prescribed by the Center for Innovation in Ship Design (CISD) and the Navy Bureau of Medicine and Surgery (BUMED). The hospital ship replacement incorporates the following capabilities:

a. Provide immediate and mobile medical services to deployed military both ashore and afloat
b. Provide mobile medical services for humanitarian aid and disaster relief in emergency situations
c. Maximize patient throughput

1.2 Background

The current hospital ships that support the U.S. Navy are the *Mercy* (T-AH-19, Figure 1) and *Comfort* (T-AH-20). These ships are converted *San-Clemente* Class tankers that were constructed in 1975 and commissioned as hospital ships in 1986. These ships are outdated and have excess internal volume; as a result, the patient throughput of the vessels is not fully efficient.

Historically, hospital ships have been primarily engaged in combat casualty care. The United States began using primitive hospital ships as early as the Civil War. The function of hospital ships at this time was merely to transport casualties back home. By World War II, hospital ships began carrying surgical teams to stabilize wounded soldiers in amphibious operations. It was not until the Korean War that hospital ships began to utilize helicopters for immediate ambulatory transport of soldiers. The USS *Consolation* (AH-15) was the first hospital ship (and, more broadly, one of the first Navy ships) to be outfitted with a helicopter pad.

Since then, hospital ships have expanded in capacity and capability. The principal characteristics of the *Mercy* Class are listed in Table 1.

Table 1: T-AH Principal Characteristics

***Mercy* Class Characteristics**	
Displacement, full load	69,360 LT
Length, overall	894 feet
Beam, overall	105 feet
Draft	33 feet
Sustained Speed	17.5 knots
Total Installed Power	18.3 MW
Power & Propulsion	2 x boilers, 2 x steam turbines, single shaft
Accommodations	1,000 Patients, 61 Civilian, 1,214 Military

Figure 1: USNS *Mercy*

The primary mission of the *Mercy* Class is to provide mobile medical and surgical services to support forces deployed ashore. These ships are engaged not only in combat casualty care, but also disaster relief and planned humanitarian operations within and outside the continental United States. While the latter two are considered secondary in priority, planned humanitarian aid and disaster relief (HA/DR) are expected to dominate the future missions of hospital ships. This refocus in mission priority is the driving factor in the redesign of medical facilities and arrangements.

Table 2 details missions that involved both USNS *Mercy* and USNS *Comfort*. A majority of the missions listed deal with HA/DR.

Table 2: Missions Performed by USNS *Mercy* and USNS *Comfort*

Mission	Details
Operations Desert Shield and Storm (1990)	• More than 8,000 outpatients and 700 inpatients seen • 337 surgeries performed
Operation Uphold Democracy (1994)	• Medical support for U.S. troops • Emergency care to Haitian civilians • Civil Affairs program to rebuild local healthcare system
Operation Sea Signal (1994)	• Aided Haitian and Cuban migrant workers
Operation Noble Eagle (2001)	• Temporary clinic for relief workers during September 11th • Treated 561 patients
Operation Iraqi Freedom (2003)	• Traveled to Persian Gulf to treat 700+ patients
Hurricanes Katrina and Rita (2005)	• Assisted the gulf coast after Hurricanes Katrina and Rita • Treated 1,956 patients in New Orleans and Pascagoula
Partnership for the Americas (2007)	• Humanitarian mission in Latin America and Caribbean. • Treated over 98,000 people in 12 different countries
Pacific Partnership (2008)	• Humanitarian and civic mission to aid Southeast Asia
Operation Unified Assistance (2010)	• Humanitarian relief effort following the Haiti earthquake • First time that *Comfort* at full capacity • Treated 1,000 patients and performed 850 surgeries

2.0 Project Directives and Constraints

The goal of this project is to design a replacement hospital ship with improved medical care capabilities. The study focused on existing hospital ships' shortcomings in the following areas:

1. **Seakeeping at zero knots** - A hull form with improved stability is required to perform medical operations during unsteady conditions. With medical staff being capable of operating during higher sea states, the throughput rate of patients will remain constant and uninterrupted and patient safety will be enhanced.
2. **Excessive draft** - A design with a shallower draft is preferred for specific missions of hospital ships. This will increase efficiency in moving casualties to/from the ship by allowing it to anchor closer to shore.
3. **Oxygen and freshwater production** - An investigation of more efficient processes in producing large amounts of oxygen and freshwater while in "unsanitary" environments. Advanced technologies and green alternatives are desirable.
4. **Modular medical spaces** - Modular medical spaces to allow rapid reconfiguration of medical spaces and possibly facilitate the movement of some medical capabilities ashore for sustained operations are desirable. Modular spaces with robust medical capabilities can provide immediate care and improve patient throughput for the humanitarian effort.
5. Additional requirements stipulated by CISD are listed in Table 3.

Table 3: Requirements for Hospital Ship Replacement

Characteristic	Requirement
Performance	
Sustained Speed	20-22 knots
Sea State Operability	SS5
Sea State Survivability	SS8
Personnel	
Crew	*TBD by team*
Medical Staff, Flight Operators, MSC Crew, etc.	*TBD by team*
Medical Facilities	
TBD by team	
Aviation Facilities	
Land/Launch Spots	2 x CH-53
Hangar	1 x CH-53, or 2 x H-60
Other	
Boat Handling	Must be capable of transferring personnel, cargo, and injured patients in calm seas
Lifeboats	Compliance with SOLAS

Not all required characteristics are listed explicitly. The premise of this project is being explored for the first time and the purpose of this investigation is to determine appropriate characteristics and requirements that can serve as a basis for further designs.

3.0 Ship Design

3.1 Concept Summary

The Hospital Ship Replacement (HSR) concept is shown in Figure 2. Principal characteristics and an equipment list for this concept are found in Table 4 and Table 5, respectively.

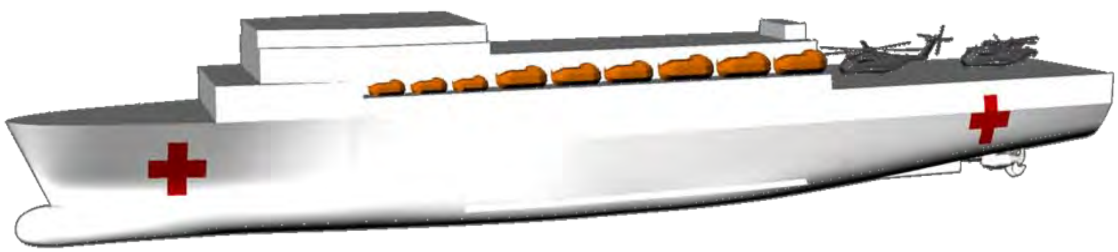


Figure 2: HSR Concept

Table 4: HSR Principal Characteristics

HSR Principal Characteristics	
Displacement	25,000 LT
LOA	684 feet
LBP	668 feet
Beam	105 feet
Draft	23 feet
Depth	62.3 feet
Mission Length	30 days
Sustained Speed	20 knots
Total Installed Power	35 MW
Propulsion	4 x Wartsila 18V32 Gensets Integrated Power System Dual azimuthing pods
Accommodations	500 patients, 72 MSC crew, 428 medical

Table 5: HSR Equipment List

Equipment	QTY
Azipod XO1800	2
Aqua-Chem Watermaker	1
Bilge Water Treatment	1
CATSCAN	1
CH-53K Helicopter	1
Crawford CB35SW Incinerator	1
ISO Container (Fully Loaded)	6
Marine Sewage Treatment	2
MCM Technologies SteriMed	1
Mitsubishi FD160N Fork Lift	1
MRI	4
Noreq Lifeboats LBT 1090 C	6
Noreq Lifeboats LBT 935 C	6
Noreq Lifeboats LBT 650 C	3
Noreq Fast Rescue Boat FRB 650 Twin 90 hp	2
Noreq Davits (36)	3
OxyPlus Oxystar99 300	2
SAIC Solid Waste Shredder	1
SAIC Plastic Waste Shredder	1
SAIC Compress Melt Unit Mod 1	1
SAIC Large Pulper	1
Wärtsilä Genset 16V32	4
X-Ray	1

3.2 Hull Form Selection

3.2.1 Selection of Monohull

Hull form selection was an extensive process in the preliminary stages of the design spiral since the project requirements were given without a specified hull form. Mission requirements, BUMED objectives, and design constraints were among the many considerations which influenced the final hull form selection. The importance of a shallower draft, improved seakeeping capabilities, and ease of patient transport to and from the platform were the driving design factors during selection.

Deliberation began with four hull form options: monohull, catamaran, trimaran and SWATH. All of these hull forms provided potential in carrying out hospital ship missions. Through initial analysis, the catamaran was removed as a serious contender. Although it is a proven hull design for stability, integrating the ability to quickly transfer patients aboard is challenging.

The SWATH was the next hull form to be ruled out. Even with increased seakeeping capabilities and good stability performance in higher sea states, this hull form posed a variety of issues. Among the issues was the weight sensitivity of the platform when moving patients and cargo around the medical

facilities. Additionally, SWATH hull forms typically have a large draft, which was something that was deemed definitely undesirable for HSR.

While the trimaran has many superior aspects such as shallow draft, hull stability and good seakeeping, the negatives aspects outweighed the positive ones. When scaled up to the desired displacement, a trimaran would have a beam of approximately 160 feet. This posed numerous issues with maneuverability and the ability to get in and out of ports and disaster areas. If the beam were to be restricted to a desirable dimension, the internal volume of a trimaran would be insufficient for the needs of a hospital ship. Thus, a monohull was selected as a more conventional and feasible design. By using a conservative monohull design, the replacement hospital ship would have an inexpensive and reliable, yet large, displacement hull form. A monohull is also an optimal choice for integrating multiple forms of ship-to-shore patient transport due to decreased weight sensitivity.

3.2.2 Comparable Ships

Once the monohull hull form was selected, it was necessary to compare vessels with similar design characteristics and determine the feasibility of scaling the vessel to the HSR's desired displacement. A displacement between 25,000 and 30,000 LT along with a draft between 20 and 28 feet was determined as a reasonable range of size for a replacement hospital ship. The range of draft considered is considerably less than the existing ships' 33-foot draft. Although commercial vessels such as cargo ships and cruise liners have similar scales of internal volume and have implemented motion reduction systems, development of a concept design for a hospital replacement ship in ten weeks required use of an existing hull form. Consequently, a limited number of naval monohull designs were available that would be scalable to the desired displacement. This tradeoff was necessary to ensure that focus for the design could be directed towards optimizing the flow of the medical facilities on the replacement hospital ship.

The initial parent hull forms considered include USNS Zeus (T-ARC 7) and USNS Safeguard (T-ARS 50), a cable laying ship and a salvage ship, respectively. Both designs were considered for their integrated systems and hull form. These ships were constructed in order to mitigate wave effects aft of the ship. This capability is essential to keep medical operations functional while afloat.

Table 6: Scaled Parent Hull Forms

		Current		Scaled	
	Unit	**T-ARS 50**	**T-ARC 7**	**T-ARS 50**	**T-ARC 7**
Length (overall)	ft	255	513	495.5	539.1
Beam	ft	51	73	103.2	86.7
Draft	ft	17	26	32.0	28.5
Displacement	LT	2,840	14,934	25,000	25,000

As shown in Table 6, neither *Zeus* nor *Safeguard* provided a considerable improvement in draft when scaled to the desired displacement of 25,000 LT. To ensure that the ship will be able to access ports

and operate nearshore, a draft less than 25 feet was desired. As a result, neither of these scaled hull forms met the design requirements.

3.2.3 LPD-17 Hull Form

Figure 3 shows the draft and displacement of a number of naval auxiliaries and aircraft carriers. The figure shows that amphibious ships have the lowest draft in the displacement range of interest. While all combatant craft remain under the desirable draft, the displacement is too little. A target displacement of 25,000 LT coupled with a desired draft of less than 25 feet hence falls into the category of amphibious vessels.

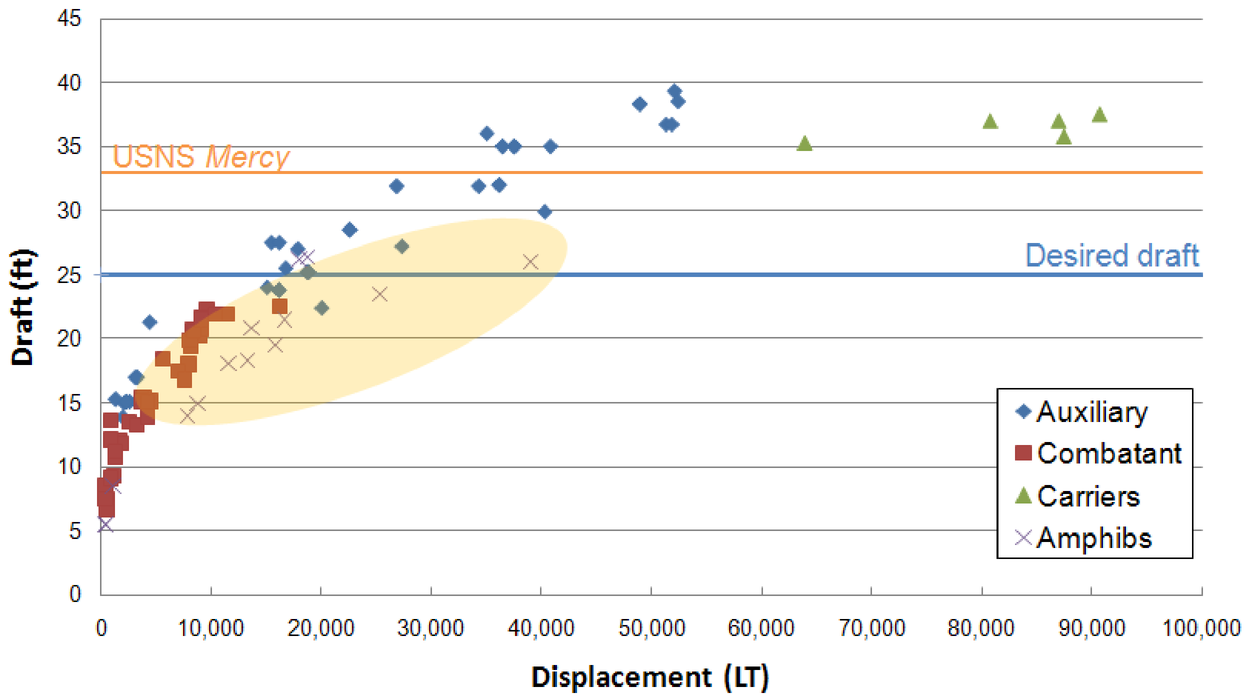


Figure 3: Draft versus Displacement for various naval vessels (Dr. Colen Kennell)

The LPD-17 *San Antonio* Class hull form was chosen in the final stages of hull form selection. This hull form's draft of 23 feet provides a ten foot draft improvement from USNS *Mercy* and USNS *Comfort*. This augments mission capabilities by increasing accessibility to ports and enabling nearshore operations. The integrated Well Deck, hangar and Flight Deck are characteristics which greatly enhance ship-to-shore capabilities for patient transport.

3.2.4 Principle Characteristics

Table 7: Principal Characteristics

	LPD-17	HSR
Length, overall (ft)	684	684
Beam, overall (ft)	105	105
Draft (ft)	23	23
Displacement, full load (LT)	24,900	24,979
Speed, sustained (knots)	22+	20
Total Installed Power (MW)	31	35
Mission Length (days)	30	30
Accommodations	1,024	500 patients 72 MSC crew 428 medical

To focus on the design and integration of the medical facilities rather than elements of the hull form, several aspects of the LPD-17 were kept constant. As seen in Table 7, the length, beam and draft of the HSR are identical to those of the LPD-17. Watertight bulkheads and decks were also kept constant. The hangar and Flight Deck were retained to preserve the capability to simultaneously land two helicopters as well as store a CH-53 K Super Stallion or a V-22 Osprey.

The Well Deck was retained to provide access and transportation of ambulance vehicles. All armament was removed to adhere to the stipulations of the Geneva Convention for hospital ships. New features to the hull form include a completely revamped deckhouse designed to the specific mission needs. Additionally, double hull fuel tanks were inserted to comply with MARPOL regulations; which states that a vessel with over 600 cubic meters fuel capacity is required to incorporate a double hull in the design.

3.3 Medical Facilities Breakdown

The decision to design a 500 bed capacity hospital ship was made in consultation with BUMED. Details of the beds and medical facilities are listed in Table 8. Although this change may appear debilitating to the mission capabilities, the HSR's medical facilities are designed to have a more efficient flow of patients and a greater patient throughput which allows the ship to accommodate the same number of patients as USNS *Mercy*, but with a smaller ship. Once the formal analysis is complete, the replacement ship should be capable of having patients brought onboard, treated, and taken off ship within 72 hours of arriving.

Table 8: Hospital Bed Breakdown

	T-AH 19 & 20	Readiness State II HA/DR
Intensive Care	80	60
Recovery	20	15
Intermediate Care	400	320
Minimal Care	500	105
Reception/Triage	50	35
Operating Room	12	6
X-Ray	4	3
Total Bed Capacity	**1,000**	**500**

The medical facilities are designed for Readiness State II as specified in the Required Operational Capability and Projected Operational Environment (ROC/POE) document. This size of medical facilities provided a solid design point for designing a replacement hospital ship. Designed in this manner, the ship can provide tailored levels of surgical-intensive care, while focusing on primary care, preventative medicine and specialized procedures more readily. This change in bed capacity and breakdown is consistent with the change in mission focus to HA/DR. Modular medical facilities will serve as the bridge to address the changes in facilities needed for combat casualty care missions.

3.4 Resistance & Power

Speed, while arguably desirable in a hospital ship, was not one of the main design drivers of this project. Ideally, sustained speed of the vessel would be around 20 knots. This speed is easily achieved for a vessel of this magnitude, and is also a 2.5 knot improvement over the current hospital ships. Maximum, or trial, speed for the design is 22 knots. The HSR speed-power curve is found in Figure 4.

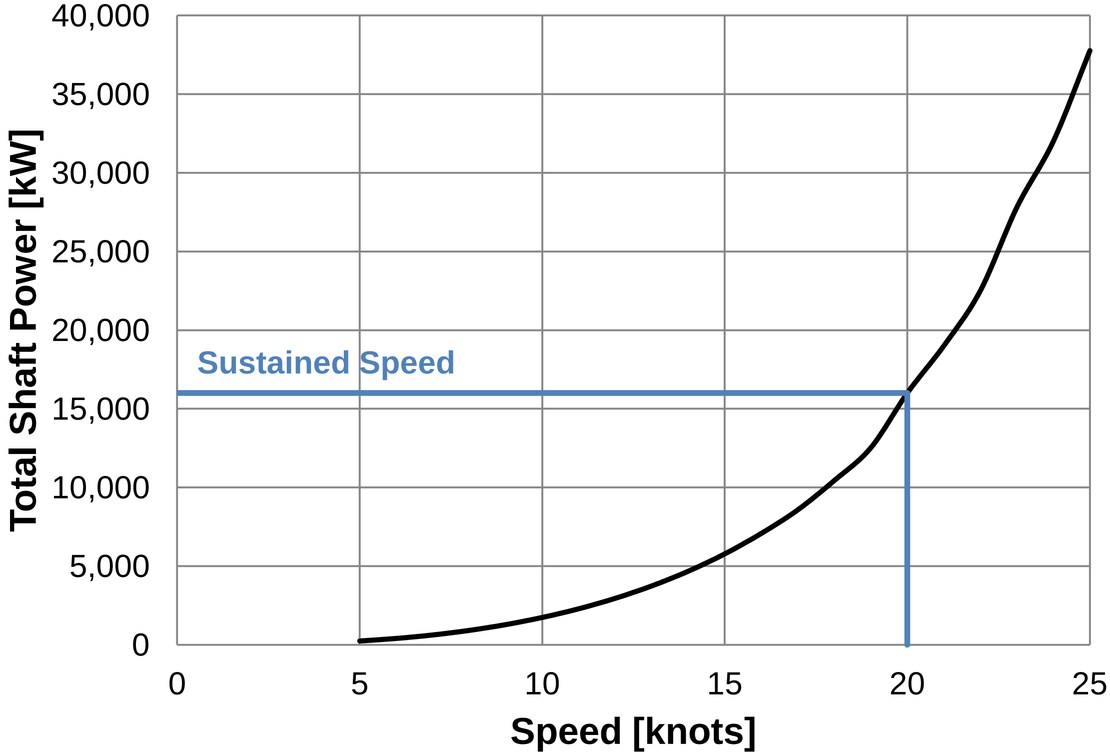


Figure 4: Required propulsion power versus speed

The hotel load of the HSR was derived from electrical load data taken from the LPD-17 (Appendix D: Electric Load Estimation). Different load cases were given depending on the ship's transient characteristics and the time of year the ship is in operation. The largest of these load cases was selected to obtain a conservative estimate. Electrical loads that were mission-specific to LPD-17 were eliminated including parts of the command and surveillance group and the entire armament group. Worst case loads for command and surveillance, auxiliary systems, and general outfits and furnishings are shown in Table 9. Together, these systems require about 4,763 kW. After adding the power that will be needed for the hospital facilities (Appendix B: Army Field Manual Information) as well as an additional margin, the hotel loads sum up to approximately 6 MW.

Table 9: Augmented LPD-17 Hotel Loads

SWBS	Component	Max power (MW)
400	Command + Surveillance	0.3
500	Auxiliary Systems	4.2
600	Outfitting + Furnishing, General	0.3
	Total Hotel Loads	**4.8**

As seen in Table 10, the HSR required operating power was estimated by combining the propulsion load (including a NAVSEA Speed-Power preliminary design margin of 10%), augmented hotel loads, and large medical power requirements.

Table 10: Total Electric Load

System	Load (MW)
Propulsion (with 10% margin)	28.3
Hotel	4.8
Medical	1.2
Total	**34.3**

Machinery systems aboard a variety of comparable ships were analyzed to determine a suitable power system. Because of the HSR's demand for large hotel loads and a high passenger capacity, power systems on cruise liners were considered since they have comparable operational functions as a hospital ship. An all electric system was selected because it has proven to be an effective power source aboard cruise liners and it also has lower fuel costs and increased efficiency compared to the USNS *Mercy's* and USNS *Comfort's* existing systems. Four Wärtsilä medium speed diesel gensets were incorporated into the design to produce the required power. Each genset provides 8.64 MW of power, supplying the ship with a total combined power of 34.56 MW.

Figure 5: Wärtsilä 18V32 Genset

3.5 Propulsion

Electric pod propulsors were selected for the design to exploit the arrangement flexibility and efficiently of the all electric design. Most of the propulsion system is contained in a suspended pod, as seen in Figure 6. The propulsors require limited space within the hull and eliminate the need for shafting. The interior volume saved was then used to improve arrangement of necessary medical spaces. The pods also produce less noise and vibration when compared to other systems, which is extremely helpful in minimizing the vibrations propagated to medical facilities.

By employing dual azimuthing pods, the design allows for increased positioning and maneuvering control of the vessel. This will be useful for a hospital ship entering or exiting disaster areas where waters are restricted for navigation and tugs are not available.

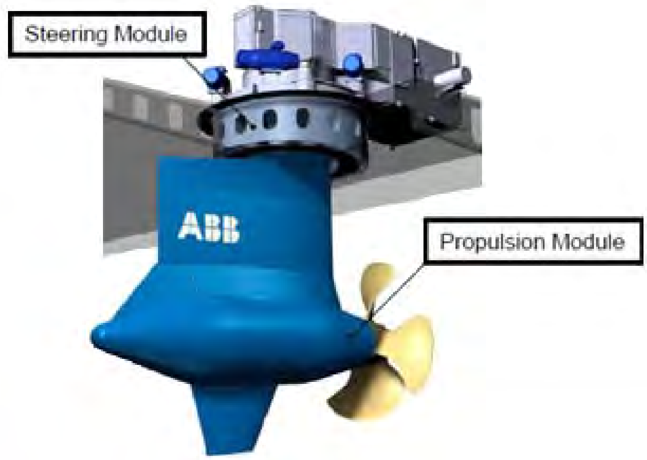


Figure 6: Azipod electric propulsor

Power is the major deciding factor when selecting a specific Azipod model. As seen in Figure 4, the design requires between 16,000 kW and 22,500 kW of propulsion power to operate within the desired speed range. By dividing these requirements in half, we were able to calculate the ideal shaft power of each pod (between 8,000 and 11,250 kW). Figure 7 shows that the Azipod model XO1800 performs within the designated power range.

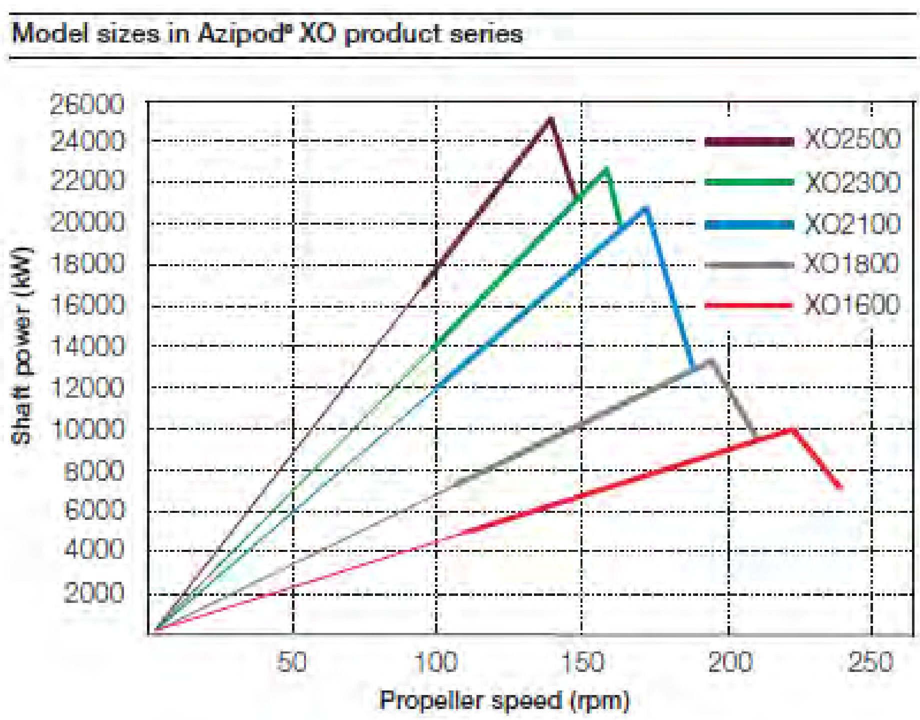


Figure 7: Azipod model comparison

3.6 Mission Systems

3.6.1 Need for Modularity

BUMED stressed that the flexibility of modular medical facilities was essential to the concept of operations. Each mission type will require specific medical facilities; tailoring of medical capabilities between two similar missions is necessary. A hospital ship that is engaged in humanitarian efforts in two different regions in the world may require different sets of medical facilities depending on the conditions of the people and the environment in each region. Figure 8 illustrates the needed flexibility for different missions; bolded areas represent the critical facilities needed.

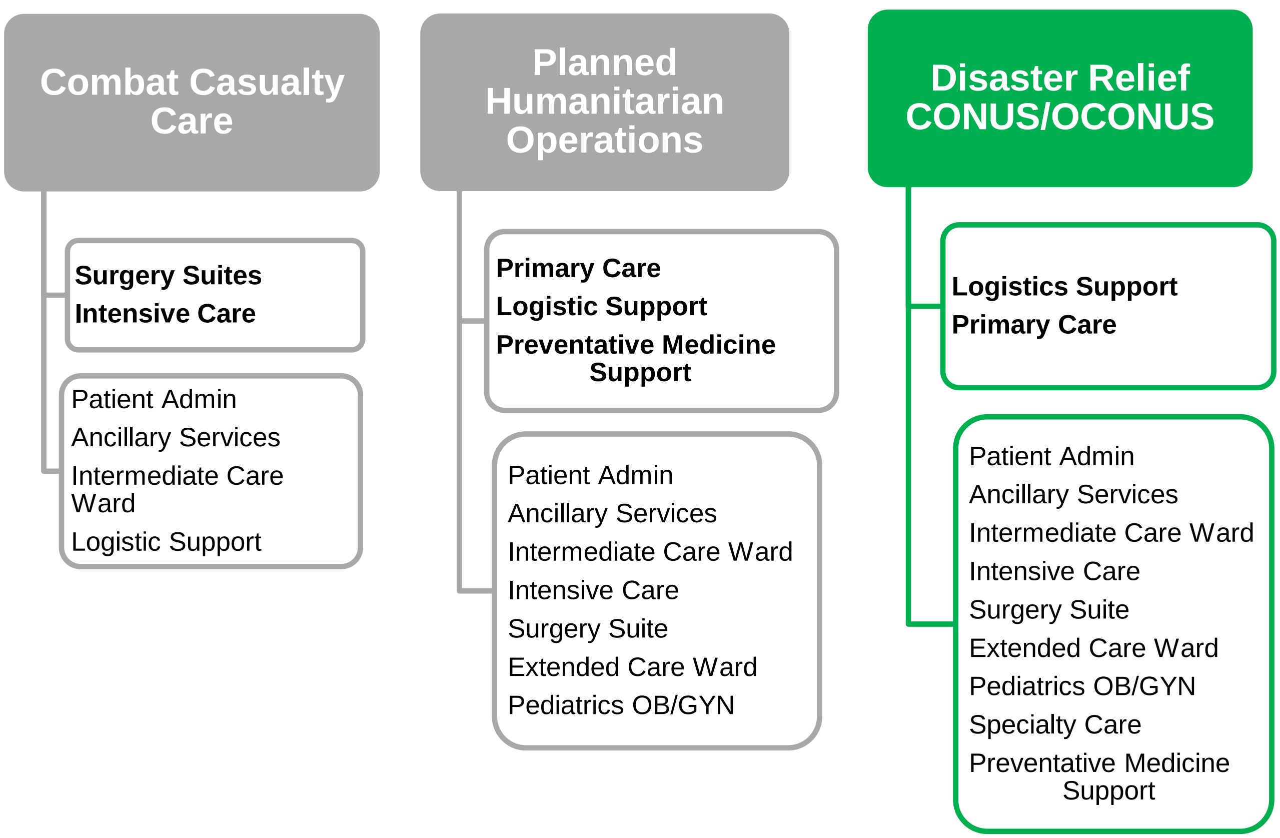


Figure 8: Mission requirements and corresponding medical facilities of HSR

The goal of the HSR design is to incorporate organic medical facilities that are common for all missions. These organic facilities will be complemented by modular medical spaces. The modular medical facilities will be integrated into the ship in two ways. First, by designating large flex spaces on board ship that will be able to be converted into a variety of medical or non-medical spaces to meet the mission-specific requirements. Second, the HSR will use ISO containers outfitted as medical spaces to provide immediate medical care on location when needed. Several of the medical facilities used onboard can fit into the capacity of an ISO container. Stowage for six of these containers is

provided in the expanded hangar- space and will be transported by helicopter to shore if needed. The combination of these two modular systems will ensure an agile and adaptable hospital ship design.

3.6.2 Flex Spaces

The flex space must be convertible into a variety of medical spaces. This means that the space must be capable of being equipped with a variety of medical services such as oxygen, water, HVAC, and electrical. The large reconfigurable medical space with be outfitted dockside before each mission to meet that mission's specific needs. For example, a primary communications center could be outfitted where facilitating communication between foreign governments, NGOs, and other entities involved in a disaster relief mission could take place. In the case of a casualty combat care mission, the flex space can be outfitted for overflow berthing, operating rooms, or immediate care wards. Figure 8 illustrates the flexibility of the space for the different mission types.

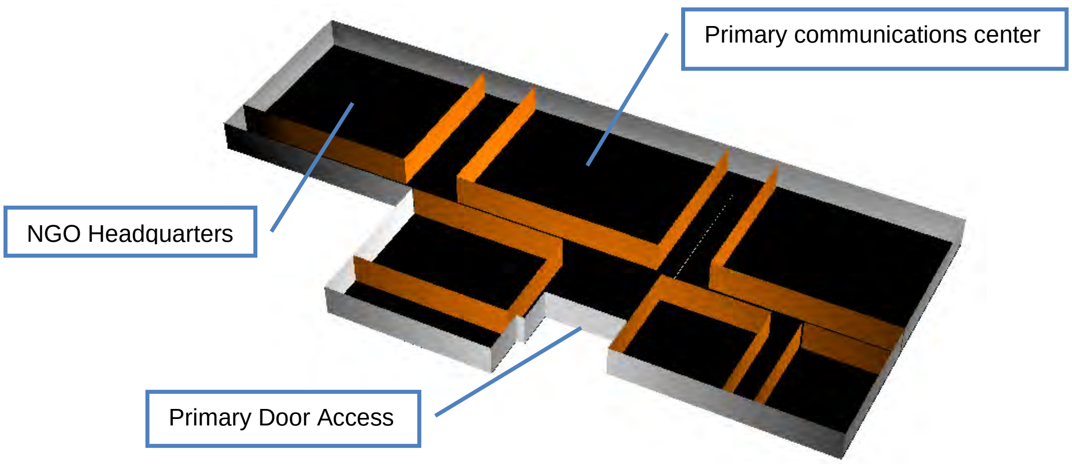


Figure 9: Example of flex space for HA/DR missions

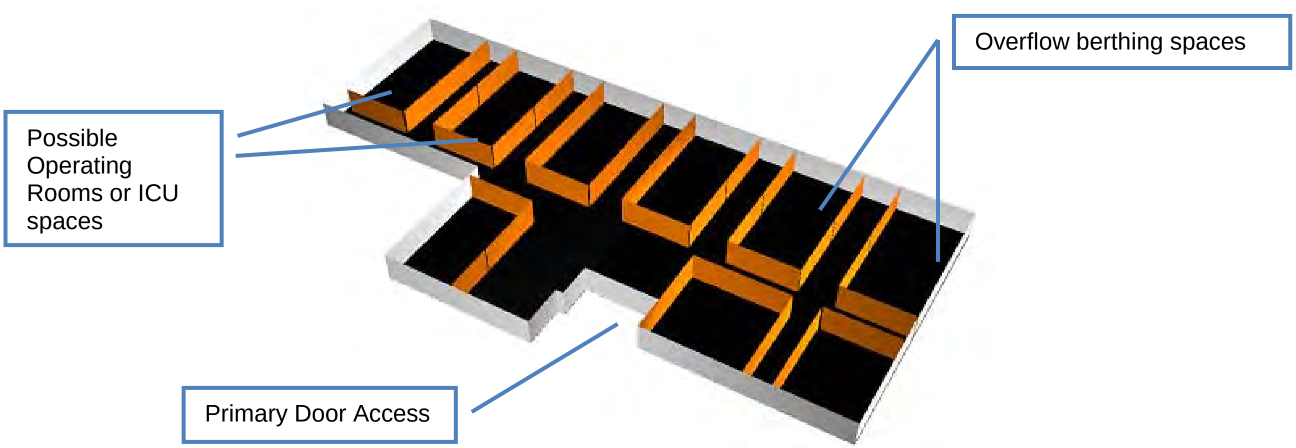


Figure 10: Example of flex space for combat casualty missions

There are two separate examples of flex space on the HSR. These flex spaces would be outfitted dockside prior to the hospital ship's mission departure. Rooms would be divided using temporary walls, which allows the spaces to be reconfigured in transit or even during the mission if necessary. The primary flex space is located on the second deck directly above the level of most critical medical care. The 21,800 square foot area is capable of being converted into a range of medical facilities for specific missions. The secondary flex space is located on the third deck and is approximately 1,660 square feet in area. Details of these spaces are found in Appendix E: General Arrangements. It is located on the level of most critical medical care and will be capable of converting into two additional operating rooms if necessary during combat casualty care missions.

3.6.3 ISO Container Systems

The HSR has the capability of loading six medically outfitted ISO containers. These portable containers can house a variety of medical facilities. The containers can be airlifted to areas inland to provide immediate medical care to disaster stricken areas. The helicopter used to transport the containers to and from the ship is discussed in detail within Section 3.8.1 Air Support.

These medical ISO containers will be stored in the garage adjacent to the hangar. A Mitsubishi FD 160N Forklift is representative of the forklift needed to move the ISO containers from the garage to the Flight Deck. It has a 110 kW, diesel powered engine and a 35,274 lbs load capacity. The containers can then be airlifted by one of the ship's helicopters. Portable generators will be required to power the containers once on site.

Medically outfitted ISO containers are commercially available. For example, DAHER KARBOX s.r.o., based in Czech Republic, manufactures a variety of medical ISO containers. Details about these containers are found in Table 11.

Table 11: DAHER KARBOX Medical ISO Containers

Dimensions (feet)	
Operating Hall Intensive Care Unit	20 x 16 x 8
Dentist Ambulance Pharmacy X-Ray Laboratory Ear, Nose, and Throat Ambulance Sterilization Room Biochemical and Hematology Laboratory Examination Room	20 x 8 x 8
Tare (lbs)	5,512 ± 5%
Maximum Gross Weight (lbs)	26,455

All containers are equipped with appropriate electrical wiring, distribution of water, a wastewater drain, lighting, heating and air conditioning. The Operating Hall and ICU both consist of two, three-walled containers. Each container lacks a sidewall where it will be connected to the other container. A removable sandwich panel closes the open wall to protect the containers when not in use. The two

containers create an operating room that has an interior area of 275 square feet. The containers that compose the Operating Hall can be airlifted separately and connected together on site with accessories stored inside the containers. Each Operating Hall can also be connected to a Pre-Operating Room container ISO and Hygiene Filter and Machine Room.

3.6.4 Fresh Water Production

BUMED has stressed the importance of adequate water production. A large portion of humanitarian aid missions take place in disaster stricken or impoverished areas where seawater is dirty or contaminated. Therefore, it was important to designate a water production system that was capable of quickly producing large amounts of potable water. Planning factors in the Army Field Manual (AFM) indicated that water requirements for the hospital ship at maximum capacity would be around 80-100,000 gallons per day (gpd). Details can be found in Appendix B: Army Field Manual Information. Fresh water capacity for the HSR was increased to 300,000 gpd to support fresh water distribution ashore during disaster relief missions (which was conducted in Haiti).

Three main water treatment techniques were considered: distillation, reverse osmosis, and filtration. Distillation is the method currently used on the USNS *Mercy* Class. Although favored for its simplicity and ability to power itself with waste products of other systems, this system was eliminated from consideration due to its large waste output, cost, and high maintenance requirements. Filtration solved these issues, requiring very little energy and cost, but this method was also eliminated because it could not meet the capacities required.

The method of choice for the HSR is reverse osmosis, which happens to also be a prospective choice for future U.S. naval ships. Reverse osmosis is capable of quickly producing large quantities of fresh water very efficiently. The water production system implemented on the hospital ship design includes a combination of a blue water reverse osmosis system and a coastal “ultra filtration” pretreatment system. Combined, this system will desalinate and decontaminate water where primary missions of this vessel will be carried out, providing safe potable water.

3.6.5 Oxygen Generation

Being essentially an isolated hospital, the ship needs to be self-sufficient in terms of oxygen production. It will not necessarily be able to rely on surrounding areas to restock its oxygen supply. According to Army Field Manuel (AFM) planning factors, a 500-patient hospital consumes around 366,828 liters of oxygen each day. An oxygen generator has been designated that is capable of producing 390,000 liters of 99.5% pure oxygen per day at a rate of 16.5 m^3/hr. This purity level complies with the U.S. Pharmacopeia standard for oxygen used for medical practice of 93% purity. To provide the clean air required by the oxygen generation system, an air compressor and treatment unit has also been designated.

Oxygen is hard-piped into essential rooms including the operating rooms, triages, flex spaces, and ICUs. Excess oxygen can be bottled and transported to various sections of the ship and ashore for

mobile operations. These pressurized cylinders will add to the emergency supply stocked onboard and be allocated for use in the event of system damage.

3.6.6 Waste Management

Waste management afloat is a constant challenge for the Navy. It is even more so when designing a hospital ship. In addition to the typical waste produced by the ship's crew and machinery, different varieties of medical waste including infectious, and noninfectious, and biohazard waste can be present. Each type has to be properly treated and disposed. If simply left to accumulate, waste storage would take up a large portion of the ship's volume.

Eight different waste management systems have been incorporated into the HSR to treat the full spectrum of waste:

- Incinerator , Crawford CB35SW Solid Waste Oxidizer
- Medical Waste Processor, SteriMed
- Solid waste shredder, SAIC
- Plastic waste shredder, SAIC
- Compress Melt Unit, SAIC
- Large pulper, SAIC
- Bilge water treatment system
- Marine sewage treatment system

The design employs two main waste systems: an incinerator and a medical waste processor. These systems allow for the disinfection and elimination of infectious waste, which cannot be stored aboard for longer than seven days.

The incinerator, a Crawford CB35SW Solid Waste Oxidizer, is a multi-chambered model capable of processing up to 100 lbs/hr of waste (Figure 11). A dual chamber system was a necessity as it allows waste to be fully sterilized before leaving the system and still maintain clean emissions. The incinerator is able to greatly reduce the volume of both medical and non-medical waste. The medical waste processor, also known as the SteriMed (Figure 12), is a specialized piece of waste management equipment that deals exclusively with medical waste. It shreds and disinfects waste, including plastic, to the point where it becomes sterile. This output can then be unloaded at generic waste facilities around the globe, as opposed to the few specialized contaminated waste treatment centers. For redundancy purposes, both of these systems were included in the concept design.

Figure 11: Crawford CB35SW Solid Waste Oxidizer

Figure 12: SteriMed Waste Processor

The five other waste management systems deal with the remaining non-medical waste produced aboard the ship. Plastic shredders paired with a compressed melt unit consolidate and store discarded plastic which cannot be discharged into the ocean. Similarly, a solid waste shredder breaks down metal and glass that can then be discharged overboard. Finally, a bilge water treatment system, a marine sewage treatment system, and a pulper are employed to deal with any remaining waste.

3.7 General Arrangements

3.7.1 Profile View

The inboard profile illustrates the location of the seven main compartments within the ship. Medical facilities are the main priority and the focus of the design; therefore, the medical facilities were centralized in the hull amidships on the main deck, 2nd deck, 3rd deck and 1st platform. By this arrangement of medical facilities, more efficient patient transfer can occur from all three modes of entry. The HSR design contains two separate machinery spaces: one amidships and one forward. The main gensets powering the propulsion system and large hotel loads are located amidships while the emergency generator is located forward. This redundancy is essential in the case of machinery failure.

	Medical Spaces		General		Machinery		Fuel & Ballast
	Decontamination		Patient Transport		Crew Spaces		

Figure 13: Inboard Profile

3.7.2 Medical Spaces

The general arrangements were developed to verify that all medical facilities and major components of the vessel could be fitted to the desired hull. More detailed arrangements can be found in Appendix E: General Arrangements. Area and volume requirements for medical spaces were scaled from the USNS *Mercy* general arrangements. All machinery, propulsion, waste, water and oxygen spaces were re-designed for the replacement hospital ship. Footprints for these various systems were acquired from vendor information. Crew accommodations were scaled based on relationships between manning numbers and the maximum patient capacity on USNS *Mercy*.

The four decks shown in Figure 14 show the layout of the main medical facilities on the HSR. Optimizing patient throughput and efficient patient flow through the hospital was the primary focus in the design. As such, it was necessary to determine which medical facilities would be organic to the ship and which would be outfitted pre-mission departure in the large reconfigurable medical space located on the 2rd deck. The 3rd deck was chosen for the level with all critical medical care facilities. This was done such that patient transport would only be one deck up from the Well Deck and two decks down from the Flight Deck entry. It was essential to centralize the medical facilities to put all medical needs such as ward beds, labs, sterile receiving, etc. directly above and below the level of critical medical care. On the critical care level, 3rd Deck, the radiology equipment, labs, operating rooms and intensive care units are kept in close proximity in a linear flow to increase patient throughput. The multiple elevators allow better patient transport between the hospital levels and add to the increased efficiency.

In the lessons learned from USNS *Mercy* and USNS *Comfort*, BUMED stressed the need for decontamination facilities at each point of entry onto the vessel. As seen on the Main Deck and 1st platform (green shaded regions), there are multiple decontamination stations located by both the Well Deck and Flight Deck entries, which is strictly used for patient decontamination. Although not depicted here, port and starboard side-hull access areas are provided with a small triage and decontamination facility. Multiple stations at each entry will increase the efficiency of patient flow and will reduce the

chance of turning into a choke point. These decontamination facilities will be protected to prevent any type of CBRNE (Chemical, Biological, Radiological, Nuclear, and Explosive) contamination in medical spaces.

	Medical Spaces		General		Decontamination		Patient Transport

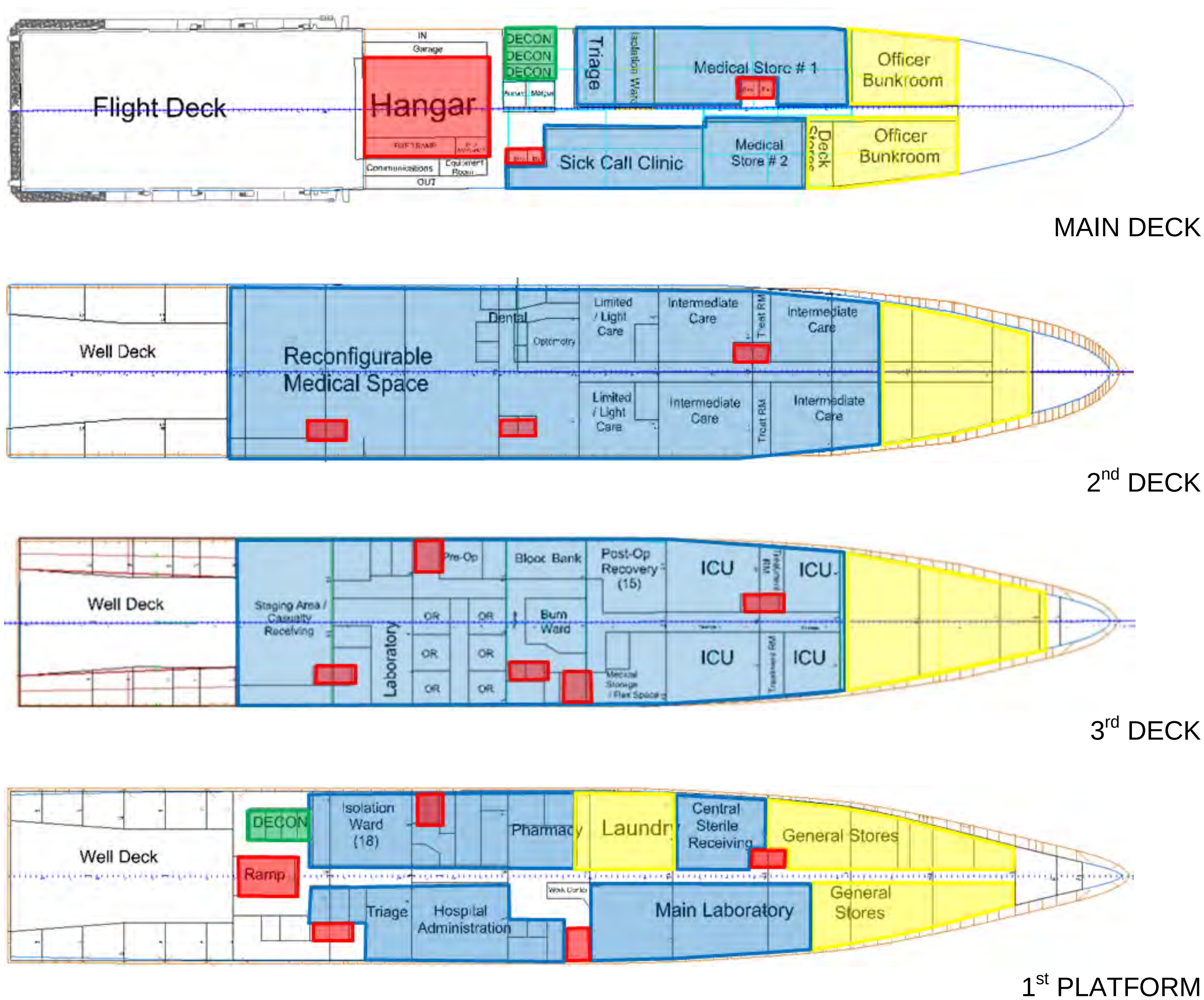


Figure 14: HSR's Medical General Arrangements

3.7.3 Collective Protection System

The HSR design includes a pressurized ventilation system known as Collective Protection System (CPS). This system is used onboard ships to protect against CBRN contamination. This system works by filtering all intake air and applying a positive air pressure to spaces to prevent contaminated air

particles from ingressing into safe areas (habitation, surgical, work, etc). Different levels of protection may be required to develop a multi-layered citadel of protection. The rooms that will be among the top tier of protection will include medical facilities that need a particularly clean environment like operating rooms, certain labs and intensive care units. A second tier will include the less critical medical facilities like wards and general ship functions such as berthing, messing, and stores. Finally, a third tier includes the machinery spaces. Decontamination stations and airlocks will be placed between any two different citadel tiers. Furthermore, the HSR will be divided into four HVAC zones that will run independently of one another and will each have their own air intake filter. If the quality of the air in one zone is compromised, it will not affect the other zones.

3.8 Ambulance Vehicles

3.8.1 Air Support

There are limited capabilities in terms of ship-to-shore air transportation on the current hospital ships. It is essential to have helicopter capabilities because it can locate and pick up patients in areas otherwise inaccessible by sea. Additionally, certain helicopters have the capability of transporting items such as ISO containers. Helicopters also provide a large range inshore and can serve as a secondary transport system to the amphibious support efforts. Although the current ships are equipped with a Flight Deck, it is only large enough to land one MedEvac helicopter. This results in a serious bottleneck as the ship loses the ability to transport large amounts of patients and cargo between the ship and the shore. Not only does the *Mercy* Class have very limited air capabilities, but also hangar facilities.

The HSR design has incorporated numerous improvements in air support. The integrated Flight Deck and hangar in the design of the LPD-17 was retained. The large Flight Deck area allows for simultaneous landing and take-off of two helicopters. The new ship design will be capable of landing a V-22 Osprey (Figure 16) on the Flight Deck and store it in the hangar. Although it is possible to have an Osprey organic to the ship, it is more feasible to choose the upcoming CH-53K Super Stallion (Figure 15) as the helicopter of choice. This helicopter has a large payload capacity which allows it to airlift the modular ISO medical care containers included in the design. It also has a very large patient capacity at 24 litters. The HSR will support two Super Stallions organic to the ship, one in the hangar and one housed on the Flight Deck. Additional structural design analysis should be facilitated to assess wind off the hangar and pressure waves from the blades of the CH-53K and V-22.

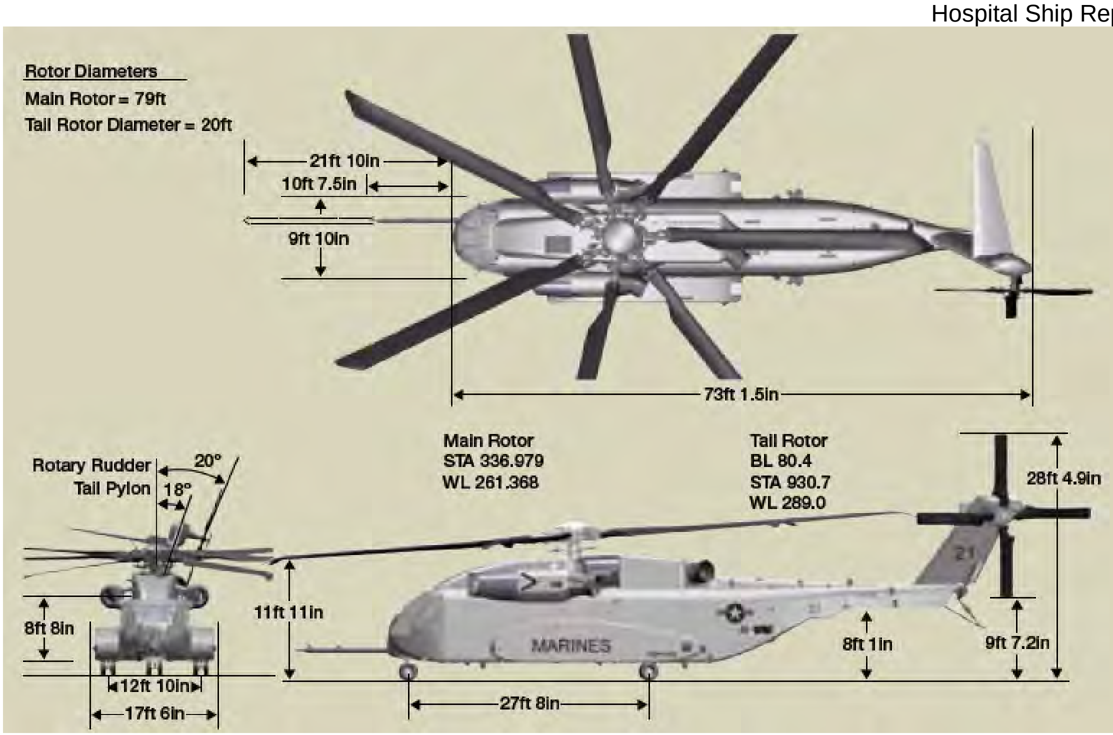


Figure 15: Sikorsky CH-53K helicopter dimensions

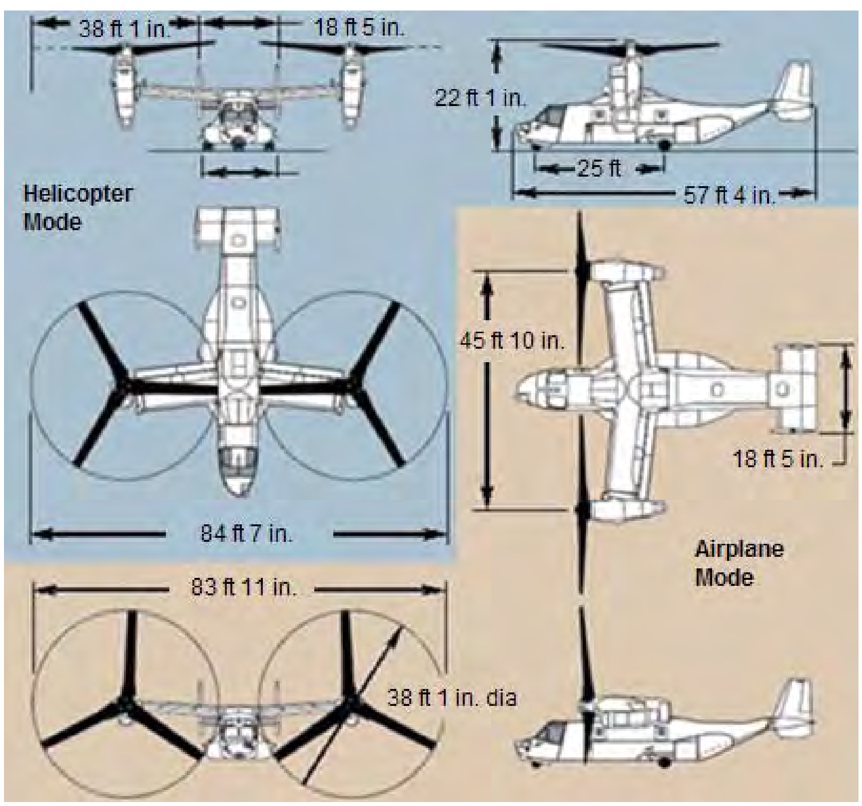


Figure 16: V-22 Osprey dimensions

3.8.2 Amphibious Support

The *Mercy* Class hospital ships are severely disadvantaged in their ability to transport patients between the ship and shore by amphibious vessels. Patients can not directly access the ship at the waterline and has limited points of entry by means of a davit lift system. While able to lower and raise the *Mercy* Class' organic ambulance boats, they can only do so in very low sea states. With this limited capability, there were immense risks associated with raising a boat transporting casualties to the boat deck. In order to resolve this issue, the Well Deck from the original LPD-17 hull form has been retained, but resized. The Well Deck will be halved in length in order to increase internal volume while retaining the capability of presenting the opportunity for a variety of organically stored ambulance craft.

Twenty-four surface craft were evaluated based on their ability to quickly and smoothly transport patients to the ship. This trade study analyzed various small craft vehicles for amphibious support based on beach slope, ship draft, vessel speed and patient capacity. Hovercrafts were determined to be the preferred mode of ambulance transportation as they not only offer improved ride quality and speed, but also are capable of driving up onto the shore. Additionally, hovercrafts provide a sufficiently large patient transfer, quick transfer times for loading and unloading of passengers, and good seakeeping in rough weather conditions.

Although the half-scale Well Deck is fully capable of housing one organic LCAC, it was determined that the Griffon 2400TD hovercraft would be a more efficient ambulance vehicle. The Well Deck is capable of housing up to four of these smaller vehicles at a time, and the ship will house two organically. This adds the benefit of redundancy and the ability to have multiple hovercrafts simultaneously accessing various locations in the same disaster area with the added benefit of extra Well Deck storage space. Details of this trade study and information on the Griffon 2400 TD hovercraft is found in Appendix C: Ambulance Craft Trade Study.

Figure 17: Griffon 2400TD hovercraft

3.9 Weights

Weight estimates were prepared utilizing the LPD-17 SWBS (Ship Work Breakdown Structure) weight report. A weight summary for the LPD-17 is shown in Table 12.

Table 12: LPD-17 Weights

SWBS	LPD-17 (LT)
100 – Hull Structures	11,614
200 – Propulsion Plant	1,053
300 – Electric Plant	904
400 – Command + Communications	486
500 – Outfitting + Furnishings	2,407
600 – Auxiliary Systems	1,527
700 – Armament	230
TOTAL	**18,221**
Loads	**6,609**
Full Load Displacement	**24,830**

A significant amount of LPD-17 mission related weights were deleted since the related systems were not needed for missions of the HSR. In Group 100, weights for structures such as 04 and 05 Deckhouse levels, ballistic plating, armament foundations, and the enclosed masts were removed. In Group 200, all weights related to the LPD-17's transmission and propulsor systems were replaced with podded system counterparts. The original medium speed turbocharged diesels in Group 300 (Electric Plant) were removed along with the existing emergency generator and replaced with weights for the HSR's integrated electric plant. Countermeasures and fire control systems were removed from Group 400 since the hospital ship is expected to comply with the Geneva Convention. In Group 500, climate control items weights were scaled to account for the increased HVAC (heating, ventilation, air conditioning) requirements of medical spaces. Group 600 weight items were scaled to reflect the increase of personnel and the rearrangement of hull spaces. Approximately 200 tons of armament were removed from Group 700, including missiles, rockets, guns, and ammunition. In addition, weights for the HSR medical equipment were inserted into the weight estimate. Table 13 lists the weights of HSR related equipment included in the weight estimate.

Table 13: Additional Medical and Ship Weights

Additional Items	Quantity	Total Weight (LT)
Medical Equipment		
CATSCAN	1	3.2
Compress Melt Unit Mod 1	1	0.6
Crawford CB35SW Incinerator	2	10.9
Medical ISO Containers (full)	6	70.9
MRI	4	47.2
Oxygen Production Units	2	1.5
SteriMed Medical Processor	1	0.7
X-Ray	1	0.2

Ship Systems		
Azipods	2	572.3
Bilge Water Treatment	1	0.7
CH-53K (organic)	1	38.8
Davits (36 person capacity)	3	15.7
FD160N Forklift	1	15.8
Large Pulper	1	1.3
Lifeboats (130 person capacity)	6	40.9
Lifeboats (102 person capacity)	6	33.1
Lifeboats (36 person capacity)	3	9.2
Marine Sewage Treatment	1	15.7
Plastic Waste Shredder	1	0.6
Solid Waste Shredder	1	0.6
Wartsila 18V32 Gensets	4	2,094.4
Water Production Unit	1	113.8
	TOTAL	**3,088.2**

HSR weights are summarized in Table 14. A 10% design margin was included in the estimate due to the moderate risk of this concept design; this margin complies with NAVSEA Instruction 9096.6B. Loads for the HSR were modified from the LPD-17 as follows:

- All cargo removed, including fuel and lubricants, amphibious assault cargo, and ordinance and delivery system cargo;
- Mission related expendables and systems removed;
- Added JP5 load to accommodate the organic CH-53K

Table 14: HSR Weights

SWBS	**HSR Concept (LT)**
100 – Hull Structures	11,020
200 – Propulsion Plant	920
300 – Electric Plant	2,733
400 – Command + Communications	296
500 – Outfitting + Furnishings	2,496
600 – Auxiliary Systems	1,774
700 – Armament	13
Total	**19,252**
Various medical items	421
Margin (10%)	1,968
Lightship + Margin	**21,641**
Loads	**3,338**
- Fuel	2,361
- Ships Force & Stores	356
- Other (non-petro based liquids, lubricating oil, etc.)	621
Full Load Displacement	**24,979**

For this concept, a comprehensive study on the structural weights is imperative. LPD-17 was built with shock-hardened structures and SSDS (Ship Self-Defense Systems). The LPD-17 hull form also employs nuclear blast protection. These self-defense systems are not needed for a hospital ship and the design does not need to comply with military design and construction standards. Furthermore, HSR must adhere to MARPOL Regulation 12A – Oil Fuel Tank Protection. This regulation states that any vessel capable of carrying over 600 m^3 of fuel is required to have a double hull structure within all fuel tanks.

Further analysis of Group 700 weights is recommended. *Mercy* Class ships carry small arms only; however, armament mounts for.50cal machine guns is being considered. The HSR accounts for carrying small arms onboard, but the gun mounts are not included. Additional analyses of certain medical weights is recommended, including medical supplies, beds, equipment, operating rooms, etc.

3.10 Seakeeping

By selecting a monohull as the basic hull form, several inherent stability issues had to be dealt with. It is important not only to overcome these issues, but also to achieve operational stability at zero knots so that the hospital can function safely. A variety of stability enhancement mechanisms were considered including gyrostabilizers, jack-up mechanisms, anti-roll tanks, and active fins.

Initially, the idea of a jack-up ship was promising as it provided the most stable platform by simply raising the hull above the impact of waves. Upon further analysis, the limitations of such a design negated its benefits. The jacks themselves are finite in length, constraining operations to shallow water. They also consume a large portion of the ships volume and add significant weight. Similarly, the righting torque provided by a gyrostabilization system requires a large amount of power to operate.

Two separate stabilization mechanisms are incorporated into the ship design. The first, a passive system, is a series of anti-roll tanks located along the centerline of the vessel. When designed correctly, these tanks are simple and relatively inexpensive. They also have the added benefit of working at any speed. In combination with anti-rolling tanks, the design incorporates an active fin stabilization system. This system is designed to operate primarily when anchored to reduce the effects of roll. Quantum markets two separate zero speed active roll fin models for small ships. Feasibility of scaling fins to the size of the hospital ship requires validation.

3.12 Lifeboats and Liferafts

The safety appliances designated for the HSR are in compliance with the Safety of Life at Sea (SOLAS) standards. Fifteen completely-enclosed lifeboats of varying sizes are capable of carrying 1,500 persons in the case of an emergency. These lifeboats, placed at various locations around the ship, account for 150% of the total passenger capacity. However, the lifeboats listed do not account for the patients that will evacuate on litters. These patients will inevitability take up more space than a seated passenger.

Table 15: Lifeboat Selection

Type	Area (sq.ft)	Dimensions (ft)	Seating	# Boats	Total Area (sq.ft)	Total Seating
LBT 650 T	160.9	21.3 x 7.5	36	3	483	108
LBT 935 T	362.3	30.7 x 11.8	102	6	2,174	612
LBT 1090 T	457.6	35.8 x 12.8	130	6	2,745	780
			TOTAL	**15**	**5,402**	**1,500**

In addition, the design includes 37 inflatable life rafts which are able to seat 125% of the total passenger capacity. Two rescue crafts, each capable of travelling at 30 knots and carrying 15 passengers, are located on the Main Deck. More information pertaining to lifeboats and liferafts is located in Appendix K: SOLAS Approved Noreq Lifeboats.

4.0 Conclusions

4.1 Summary

The need to replace the existing hospital ships is a rising concern for the U.S. Navy. As the USNS *Mercy* and USNS *Comfort* reach the end of their service life, the fleet will need to replace these ships with a modern, more efficient hospital ship that will be able to efficiently satisfy the ship's missions. This project has produced a ship design that incorporates features that are desirable in a new hospital.

The outfit of the HSR can be tailored to the different missions of hospital ships: humanitarian missions, disaster relief, and combat casualty care. By incorporating medical ISO container systems and large, flex spaces, the design can provide modular medical facilities in response to the variety of missions.

The 25,000 LT HSR design provides solutions to a number of issues that have been encountered with the existing hospital ships. By scaling down to a 500-bed capacity and using a different hull form, the HSR has a shallower draft; the ship is then capable of accessing a wider range of ports as well as anchoring closer to shore during its missions. With the integration of both a Well Deck and Flight Deck, it provides an efficient system for patient transport by both sea and air, thus increasing patient throughput. It uses an integrated power system comprised of four diesel gensets along with dual electric pod propulsors to improve maneuverability. Anti-roll tanks and zero-speed active fins are included in the design to improve seakeeping at zero knots to enhance safety during medical procedures. Modern systems for both freshwater and oxygen production have been selected to meet the demands of hospital operations.

4.2 Future Work

The HSR is a solid base design for future development of a new hospital ship. If this design effort was to be continued, several opportunities for future work are recommended.

Further evaluation of requirements of the hospital ship needs to be revisited. Although the HSR has incorporated means of reducing motions at anchor, the seakeeping requirement needs to be quantified so that a trade study of other motion-damping systems can be conducted. While the LPD-17 structure, subdivision, and structural weight were the bases for the HSR design, the structural design of the hull is inappropriate for the hospital ship mission. LPD-17 structure was constructed with nuclear blast protection, shock protection, and to comply with numerous military standards such as those governing stability after damage. By comparison, hospital ship structure should be designed to commercial standards and classed under the American Bureau of Shipping (ABS) Steel Vessel Rules. Designing to commercial standards will result in a more producible and lower cost ship. Use of appropriate damage stability standards in combination with ABS structures may reduce the number of bulkheads needed to facilitate a more efficient arrangement of the ship. The more efficient arrangement may be particularly important in streamlining medical operations.

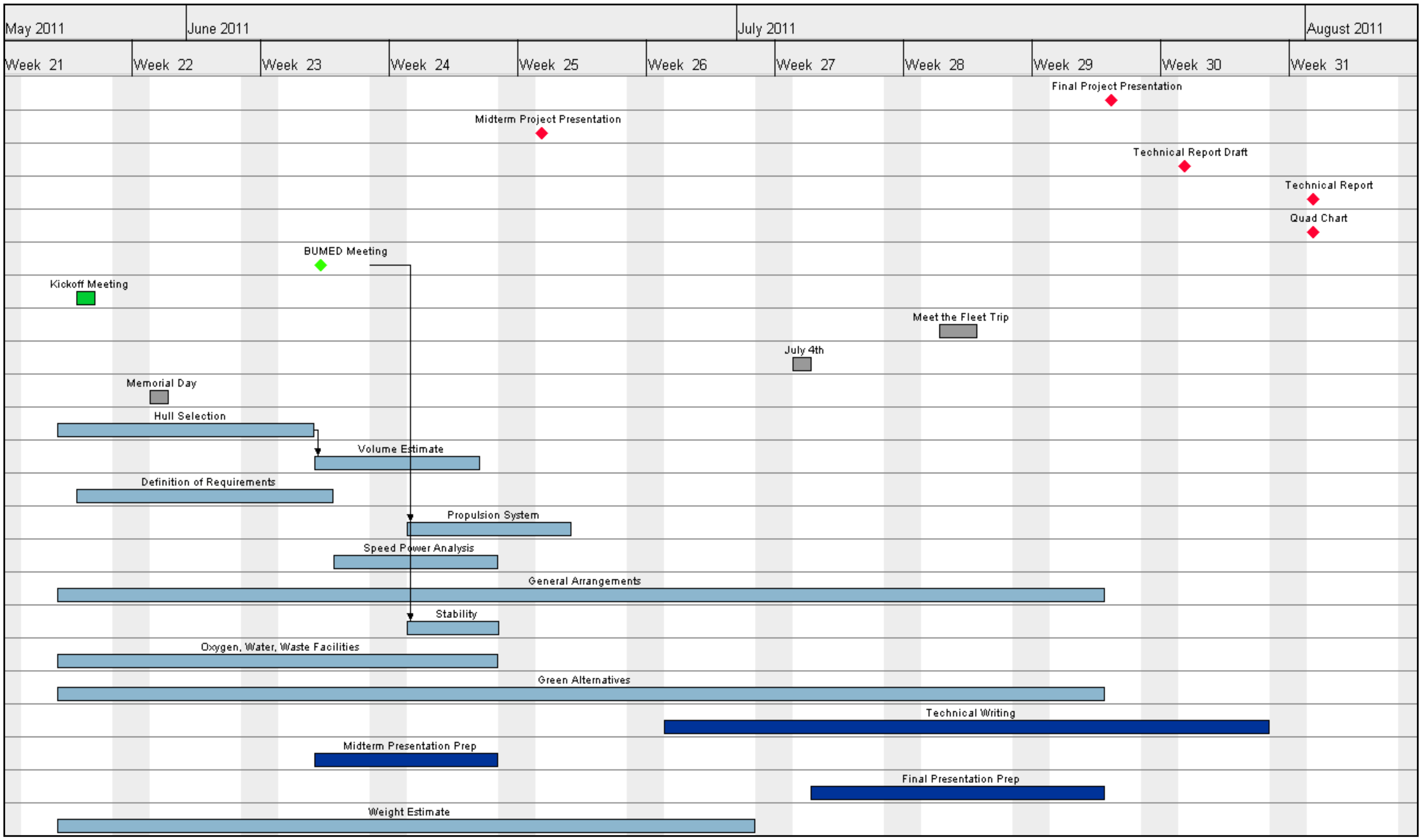
Ship producibility studies have identified numerous design features that enhance producibility and reduce ship cost. The HSR design did not incorporate many of these features. Design features such as higher deck heights and/or dedicated passageways to facilitate installation/maintenance of distributive systems and limited numbers of structural plate sizes and shapes should be explored in future design work.

The importance of surface ambulances and the Well Deck have been identified in this design. Further evaluation of ambulance alternatives and the related Well Deck design are recommended. Ballast system requirements to support ambulance operations also warrant review.

Finally, a look into possible green design alternatives would help pinpoint opportunities within the design for ecological improvement. For example, an exploration of fuel cell technology would help reduce fuel consumption onboard without eliminating essential systems while reducing noise and vibration in the ship.

Appendices

Appendix A: Project Gantt Chart



Appendix B: Army Field Manual Information

The HSR design used the same specifications as the field hospital in the Army Field Manual. This field hospital information was obtained from the Army Field Manual: Hospital Planning Factors. The information contains planning factors for personnel, transportation and movement, supply, personnel service support, CHS planning for hospitalization, and engineer requirements. The following tables are specifications for a field hospital.

There are two water consumption tables. The Water Consumption (2) was chosen as the water consumption specifications for the HSR, because it requires more water and thus was deemed to be a more conservative specification.

Table 16: Planning Factors

Food Storage				
	Meals/Pallet	Total Meals	Total Pallets	Volume of Pallet [cu. ft]
Patients	400	45,000	112.5	5,187.5
Crew	400	44,910	112.3	5,177.1
Total		**89,910**	**224.8**	**10,364.6**

Water Consumption (1)					
Personnel	**Consumptive Factors**	**Gallons/Day**	**Volume/Day [cu. ft/day]**	**Volume [cu. ft]**	**Volume [gallons]**
Total Patients	(# beds) x 17.25	8,625	1,153	34,592	258,750
OR	(# beds) x 19	9,500	1,270	38,102	285,000
ICU	(# beds) x 22	11,000	1,471	44,118	330,000
Minimal Care	(# beds) x 10	5,000	668	20,054	150,000
Crew	(# crew) x 10.25	5,115	684	20,514	153,443
Crew (40%)	(# crew) x 9.4	4,691	627	18,813	140,718
	Total	**43,931**	**5,873**	**176,191**	**1,317,911**
Decontamination		**Gallons/Day**	**Volume/Day [cu. ft/day]**	**Volume [cu. ft]**	**Volume [gallons]**
7 gallons per individual		7	1	28	210
380 gallons per major end item		380	51	1,524	11,400
	Total	**387**	**52**	**1,552**	**11,610**
Vehicle Maintenance		**Gallons/Day**	**Volume/Day [cu. ft/day]**	**Volume [cu. ft]**	**Volume [gallons]**
1 gallon per vehicle (hot climate)		1	0.1	4	30
Loss/waste factor = 10 % of total req.		973	130	3,904	29,200
	Total	**974**	**130**	**3,908**	**29,230**
	Total hospital need	**45,292**	**6,055**	**181,651**	**1,358,750**

Water Consumption (2)					
Crew	**Consumptive Factors [gal/man/day]**	**Gallons /Day**	**Volume/Day [cu. ft/day]**	**Volume [cu. ft]**	**Volume [gallons]**
Drinking	1.5	749	100	3,002	22,455
Hygiene	1.7	848	113	3,402	25,449
Food Prep	1.8	873	117	3,502	26,198
Extra Showers	5.3	2,645	354	10,607	79,341
Wastewater	7.0	3,493	467	14,009	104,790
	Total	**8,608**	**1,151**	**34,523**	**258,233**
Patient	**Consumptive Factors [gal/man/day]**	**Gallons /Day**	**Volume/Day [cu. ft/day]**	**Volume [cu. ft]**	**Volume [gallons]**
Cleanup	1.0	500	67	2,005	15,000
Heat Treatment	0.2	100	13	401	3,000
Bed bath	5.0	2,500	334	10,027	75,000
Hygiene	1.7	850	114	3,409	25,500
Bed pan wash	1.5	750	100	3,008	22,500
Lab	0.2	100	13	401	3,000
Sterilizer	0.2	100	13	401	3,000
X-ray	0.2	100	13	401	3,000
Hand Washing	2.0	1,000	134	4,011	30,000
Cleanup	1.0	500	67	2,005	15,000
Wastewater	12.0	6,000	802	24,064	180,000
	Total	**12,500**	**1,671**	**50,134**	**375,000**
Surgical	**Consumptive Factors [gal/man/day]**	**Gallons /Day**	**Volume/Day [cu. ft/day]**	**Volume [cu. ft]**	**Volume [gallons]**
Scrub	10.0	120	16	481	3,600
Instrument Wash	4.0	48	6	193	1,440
OR cleanup	5.0	60	8	241	1,800
Wastewater	19.0	228	30	914	6,840
	Total	**456**	**61**	**1,829**	**13,680**
Laundry	**Consumptive Factors [gal/man/day]**	**Gallons /Day**	**Volume/Day [cu. ft/day]**	**Volume [cu. ft]**	**Volume [gallons]**
Bed patients	22.0	11,000	1,471	44,118	330,000
Ambulatory Patients	10.0	5,000	668	20,054	150,000
Staff Smocks	9.4	4,700	628	18,850	141,000
Wastewater	41.4	20,700	2,767	83,021	621,000
	Total	**41,400**	**5,535**	**166,043**	**1,242,000**
Decontamination	**Consumptive Factors [gal/man/day]**	**Gallons /Day**	**Volume/day [cu. ft/day]**	**Volume [cu. ft]**	**Volume [gallons]**
Individual	7	175	23	702	5,250

Major end item	380	9,500	1,270	38,102	285,000
Vehicle Main't	450	11,250	1,504	45,120	337,500
Total		**20,925**	**2,798**	**83,924**	**627,750**
Miscellaneous	**Consumptive Factors [Gal/meal/day]**	**Gallons /Day**	**Volume/Day [cu. ft/day]**	**Volume [cu. ft]**	**Volume [gallons]**
Water used for food (Crew)	928		-	-	
Water used for food (Patients)	928		-	-	
Total		**167,777**	**22,430**	**672,904**	
Total hospital need		**83,889**	**11,215**	**336,452**	**2,516,663**

Solid Waste					
	Production Factor	**Gallons/Day**	**Volume/Day [cu. ft/day]**	**Volume [cu. ft]**	**Volume [gallons]**
Total Patients	(# beds) x 15 lbs	7,500	1,003	30,080	225,000
Crew	(# crew) x 12.5	250	33	1,003	7,500
Total		**7,750**	**1,036**	**31,083**	**232,500**

Oxygen Requirements				
	Consumption Rate [liters/Day]	**Volume [liters]**	**Volume [cu. ft]**	**Total # of H Cylinders**
OR Table Hours	96,768	2,903,040	82,214,093	466
ICU Beds on Vent	191,601	5,748,030	162,784,210	923
EMT & Other Requirements	77,760	2,332,800	66,064,896	374
Pneumatic Instruments	699	20,970	593,870	4
Total	**366,828**	**11,004,840**	**311,657,069**	**1,767**

Blood Storage				
		Total # Units	**Total # Refrigerators**	**Total Refrigerator Surface Area [sq. ft]**
Red Blood Cells	4 units/ patient/ day	60,000	83	1,217
Fresh Frozen Plasma	.08 units/ patient/ day	1,200	2	24
Frozen Platelet Concentrate	.04 units/ patient/ day	600	1	12
Total		**61,800**	**86**	**1,254**

Laundry		
	Total Weight per person/day (lb)	**Hourly wash 25 kg/hr**
Weight of clothing to be washed per day (4 lbs for personnel and 8 lbs for patients)	5,996	2,611

Fuel Consumption				
	Gal/Day	Weight (lb)	Volume (cu. ft)	Volume (gallons)
Diesel	997	7,011	134	29,918
Total	**997**	**7,011**	**134**	**29,918**

Table 17: Summary Table of Field Hospital

FH Requirements/Assumptions	Input
Number of Patients (total)	500
Number of Surgical cases (OR beds) maximum	16
Number of bed patients (ICU beds)	60
Number of minimal care patients	105
Number of Decontamination Cases	15
Number of crew (hospital and civil service)	499
Number of days	30
Generator power output (Continuous kilowatts)	
Generator fuel consumption (gph)	
Daily power requirement (kW)	1384

Table 18: HSR in comparison to the USNS Mercy and Comfort

	Mercy/ Comfort	New Design (1/2)	State II (HA/DR)
Intensive Care	80	40	60
Recovery	20	10	15
Intermediate Care	400	200	320
Minimal Care	500	250	105
Operating Room	24	12	12
X-Ray	4	2	3
Reception/ Triage	50	25	35
Total Bed Capacity	1000	500	500

Table 19: HSR Crew

State II (HA/DR)	
Hospital Crew	428
Civil Service Mariners	71
Total Crew	499

Appendix C: Ambulance Craft Trade Study

Table 20: Ambulance Craft Analyzed in Trade Study

Ambulance Craft	Length [m]	Beam [m]	Passengers [max]	Max. Payload [tons]	Speed [knots]	Well Deck Capacity [# of craft]
Griffon 380TD	6.8	3.76	5	0.38	30	4
Griffon 500TD	8.04	3.92	5	0.47	30	4
Griffon 2000TD	12.7	6.1	20	2	35	4
Griffon 2400TD	13.4	6.8	25	2.4	30	4
Griffon 3000TD	18.4	10.1	42	4	37	2
Griffon 8000TD	21.3	11	85	9.3	45	1
Griffon 8100TD	22.55	11	98	12	45	1
Griffon BHT130	29.3	15	130	20	45	1
Griffon BHT150	31	15	150	22.5	45	1
Griffon BHT 160	32.3	15	160	22.5	45	1
Griffon BHT 180	33.7	15	180	22.5	45	1
Hovertechnics Hoverguard 1000	5.87	2.44	5	0.6	35	4
Hovertechnics Hovertour 2000	6.7	2.44	5	0.75	35	4
LCAC	26.40	14.30	180	60	40	1
LCU	41.12	8.80	400	170	8	1
LCM 8	22.50	6.40	200	60	9	2
LCM 6	17.10	4.30	80	34.4	9	2
RIB	10.98	3.23	15	1.6	45	4
AAVP-7	9.79	3.93	18	4.5	7.3	4
AAAV	10.67	3.66	17	5.0	20	4
Hover Probe 2000	6.71	2.74	5	0.75	30.4	4
Ambulance Boat	8.50	2.51	12	4.35	30	4
Rescue Eagle Rib	15.00	3.59	40	13.2	30	3
Rescue Eagle Hovercraft	9.63	4.41	16	2	35.1	4

Assumptions:

1. Draft of HSR is 23 feet
2. Time to load each patient in a hovercraft = 1 minute
3. Time to load each patient in other small craft = 2 minutes

Table 21: Beach slope 1/20

Beach Slope =	0.050
Draft [ft] =	23
Distance to Ship [ft] =	460

Ambulance Craft	Time for (un)loading [hr]	Time per Roundtrip [hr]	Trips Per Hour	Patients Per Hour (max)
Griffon 380TD	0.08	0.17	5.82	116.47
Griffon 500TD	0.08	0.17	5.82	116.47
Griffon 2000TD	0.33	0.67	1.49	119.23
Griffon 2400TD	0.42	0.84	1.19	119.28
Griffon 3000TD	0.70	1.40	0.71	59.83
Griffon 8000TD	1.42	2.84	0.35	29.96
Griffon 8100TD	1.63	3.27	0.31	29.97
Griffon BHT130	2.17	4.34	0.23	29.98
Griffon BHT150	2.50	5.00	0.20	29.98
Griffon BHT 160	2.67	5.34	0.19	29.98
Griffon BHT 180	3.00	6.00	0.17	29.98
Hovertechnics Hoverguard 1000	0.08	0.17	5.85	116.96
Hovertechnics Hovertour 2000	0.08	0.17	5.85	116.96
LCAC	3.00	6.00	0.17	29.98
LCU	13.33	26.69	0.04	14.99
LCM 8	6.67	13.35	0.07	29.96
LCM 6	2.67	5.35	0.19	29.91
RIB	0.50	1.00	1.00	59.80
AAVP-7	0.60	1.22	0.82	58.98
AAAV	0.57	1.14	0.88	59.60
Hover Probe 2000	0.08	0.17	5.83	116.52
Ambulance Boat	0.40	0.81	1.24	59.62
Rescue Eagle Rib	1.33	2.67	0.37	44.91
Rescue Eagle Hovercraft	0.27	0.54	1.86	119.04

Table 22: Beach slope 1/100

Beach Slope =	0.010
Draft [ft] =	23
Distance to Ship [ft] =	2,300

Ambulance Craft	Time for (un)loading [hr]	Time per Roundtrip [hr]	Trips Per Hour	Patients Per Hour (max)
Griffon 380TD	0.08	0.19	5.21	104.22
Griffon 500TD	0.08	0.19	5.21	104.22
Griffon 2000TD	0.33	0.69	1.45	116.23
Griffon 2400TD	0.42	0.86	1.16	116.47
Griffon 3000TD	0.70	1.42	0.70	59.14
Griffon 8000TD	1.42	2.85	0.35	29.82
Griffon 8100TD	1.63	3.28	0.30	29.85
Griffon BHT130	2.17	4.35	0.23	29.88
Griffon BHT150	2.50	5.02	0.20	29.90
Griffon BHT 160	2.67	5.35	0.19	29.91
Griffon BHT 180	3.00	6.02	0.17	29.92
Hovertechnics Hoverguard 1000	0.08	0.19	5.31	106.22
Hovertechnics Hovertour 2000	0.08	0.19	5.31	106.22
LCAC	3.00	6.02	0.17	29.91
LCU	13.33	26.76	0.04	14.95
LCM 8	6.67	13.42	0.07	29.81
LCM 6	2.67	5.42	0.18	29.53
RIB	0.50	1.02	0.98	59.01
AAVP-7	0.60	1.30	0.77	55.23
AAAV	0.57	1.17	0.85	58.06
Hover Probe 2000	0.08	0.19	5.22	104.40
Ambulance Boat	0.40	0.83	1.21	58.17
Rescue Eagle Rib	1.33	2.69	0.37	44.58
Rescue Eagle Hovercraft	0.27	0.55	1.80	115.34

Table 23: Beach slope is 1/500

Beach Slope =	0.002
Draft [ft] =	23
Distance to Ship [ft] =	11,500

Ambulance Craft	Time for (un)loading [hr]	Time per Roundtrip [hr]	Trips Per Hour	Patients Per Hour (max)
Griffon 380TD	0.08	0.29	3.41	68.30
Griffon 500TD	0.08	0.29	3.41	68.30
Griffon 2000TD	0.33	0.77	1.29	103.25
Griffon 2400TD	0.42	0.96	1.04	104.22
Griffon 3000TD	0.70	1.50	0.67	55.91
Griffon 8000TD	1.42	2.92	0.34	29.14
Griffon 8100TD	1.63	3.35	0.30	29.25
Griffon BHT130	2.17	4.42	0.23	29.43
Griffon BHT150	2.50	5.08	0.20	29.50
Griffon BHT 160	2.67	5.42	0.18	29.53
Griffon BHT 180	3.00	6.08	0.16	29.59
Hovertechnics Hoverguard 1000	0.08	0.27	3.64	72.78
Hovertechnics Hovertour 2000	0.08	0.27	3.64	72.78
LCAC	3.00	6.09	0.16	29.53
LCU	13.33	27.14	0.04	14.74
LCM 8	6.67	13.75	0.07	29.08
LCM 6	2.67	5.75	0.17	27.81
RIB	0.50	1.08	0.92	55.34
AAVP-7	0.60	1.72	0.58	41.90
AAAV	0.57	1.32	0.76	51.41
Hover Probe 2000	0.08	0.29	3.43	68.69
Ambulance Boat	0.40	0.93	1.08	51.83
Rescue Eagle Rib	1.33	2.79	0.36	42.97
Rescue Eagle Hovercraft	0.27	0.64	1.56	99.82

Appendix D: Electric Load Estimation

Table 24: Electric Load Estimates that Apply to HSR

HSR Hotel Loads		
SWBS	**Component**	**Max power**
400	**Command + Surveillance**	**256.4**
410	**Command and Control Systems**	**64.4**
411	Data Display Group	34.5
412	Data Processing Group	29.9
430	**Interior Communications**	**40**
440	**Exterior Communications**	**152**
441	Radio Systems	152
450	**Surface Surveillance System**	**0**
451	Surface Search Radar	x
455	Identification Systems	x
456	Multiple Mode Radar	x
460	**Underwater Surveillance**	**0**
461	Active Sonar	x
466	Lamps Electronics	x
470	**Countermeasures**	**0**
472	Passive ECM	x
473	Torpedo decoys	x
474	Decoys (Other)	x
490	**Special Purpose System**	**0**
491	Elctrnc Test,Checkout,Mon	x
493	Non-combat data process	x
500	**Auxiliary Systems**	**4,162.90**
510	**Climate Control**	**3,304.90**
511	Compartment Heating Systems	1,513.60
512	Ventilation Systems	871.1
514	AC systems	900
516	Refrigeration Systems	20.2
520	**Sea Water Systems**	**213.1**
521	Firemen +Sea water flush	211.1
529	Drainage + Ballasting System	2
530	**Fresh Water Systems**	**343.7**
531	Distilling Plant	67.1
532	Cooling Water	12.4
533	Potable Water	264.2
540	**Fuels/Lubricants, Handling**	**69.8**
541	Ship Fuel + Compensating	47.3
542	Aviation + General Purpose	22.5
550	**Air, Gas+MISC Fluid System**	**48.8**
551	Compressed Air System	48.8
560	**Ship Control Systems**	**110.1**
561	Steering and Driving Controls	110.1

580	**Mechanical Handling System**	**36.2**
583	Boats, Handling, and Storage	16
584	Mech Oper Door,Gate,Ram	10.4
588	Aircraft Handling, Service	9.8
590	**Special Purpose Systems**	**36.3**
593	Environmental Pollution	36.3
600	**Outfitting + Furnishing, General**	**344.2**
620	**Hull Compartmentation**	**23.4**
625	Airports, Fixed Portlights	23.4
630	**Perservatives+Coverings**	**18**
633	Cathodic Protection	18
650	**Service Spaces**	**250.9**
651	Commissary Space	157.3
652	Medical Space	11.3
655	Laundry Space	79.1
656	Trash Disposal Spaces	3.2
660	**Working Spaces**	**51.9**
665	Workshops, Labs, Test Areas	51.9

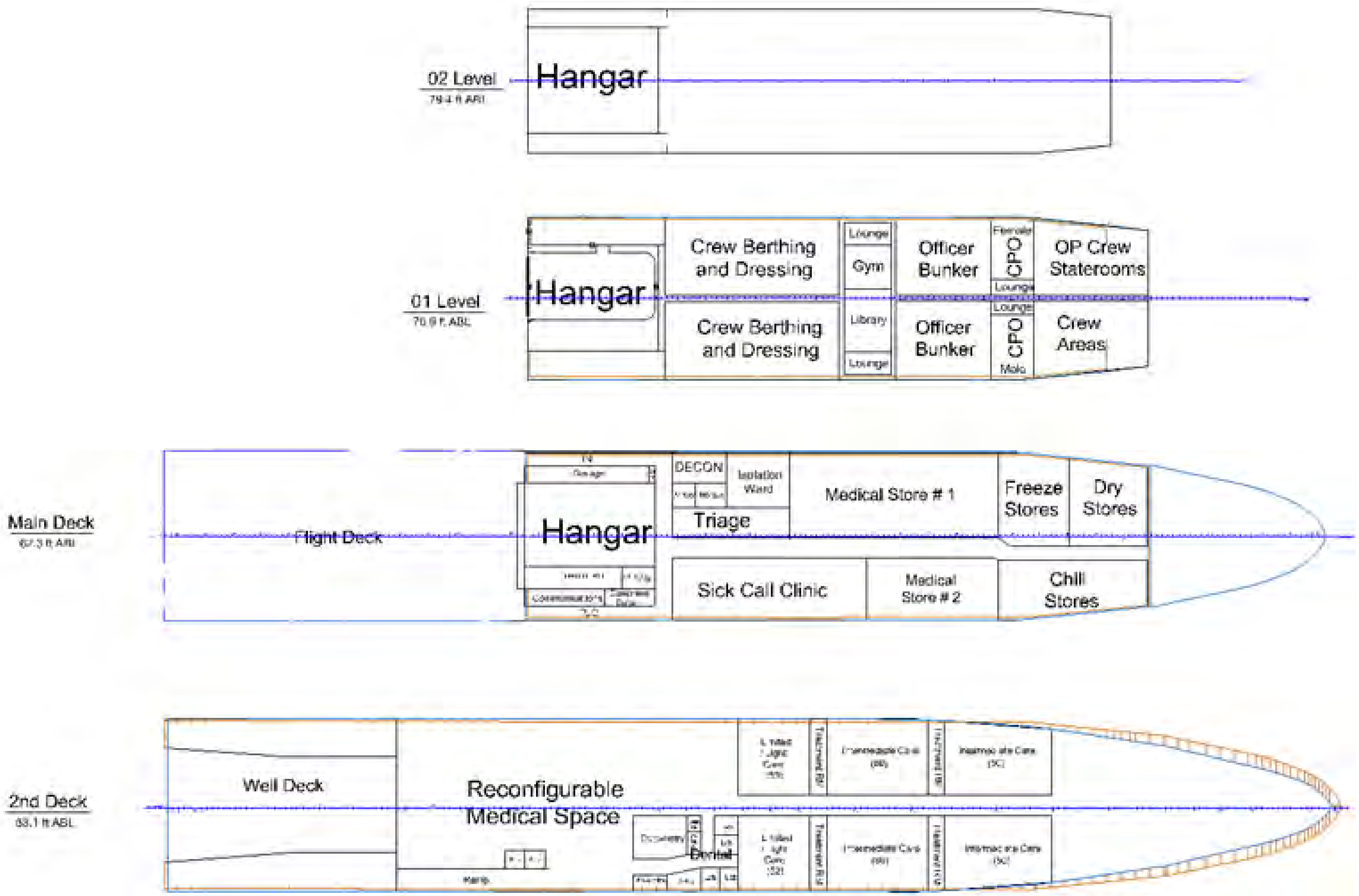
Table 25: Electric Load Data for LPD-17

LPD 17 Electrical Load Data		
Elect Load Des Margin Fac		-
Elect Load Sl Margin Fac		0.2
400-Hz Elect Load Fac		0.1
Max 400-Hz Elec Load		48.4
24-Hr Avg Elect Load		3,573.4
Total Summer Cruise Load		4,705.8
Connected Elect Load		14,516.3
Total Winter Cruise Load		5,477.8
Max Marg Elec Load		6,538.1
Total Summer Launch Load		5,102.5
Max Stby Elect Load		5,034.4
Total Winter Launch Load		5,117.8
Vital Elect Load		5,034.4
Total Anchor Load		4,946.8
Total Emergency Load		1,574.4
200	**Propulsion Plant**	**36.30**
230	**Propulsion Units**	**7.30**
233	Diesel Engines	7.30
234	Gas Turbines	-
240	**Transmission + Propulsors**	**4.00**
241	Reduction Gears	4.00
243	Shafting	2.60
245	Propulsors	-
250	**Support Systems**	**11.20**
251	Combustion Air System	-
252	Propulsion Control Sys	11.20
256	Circ + Cool Sea Water	-

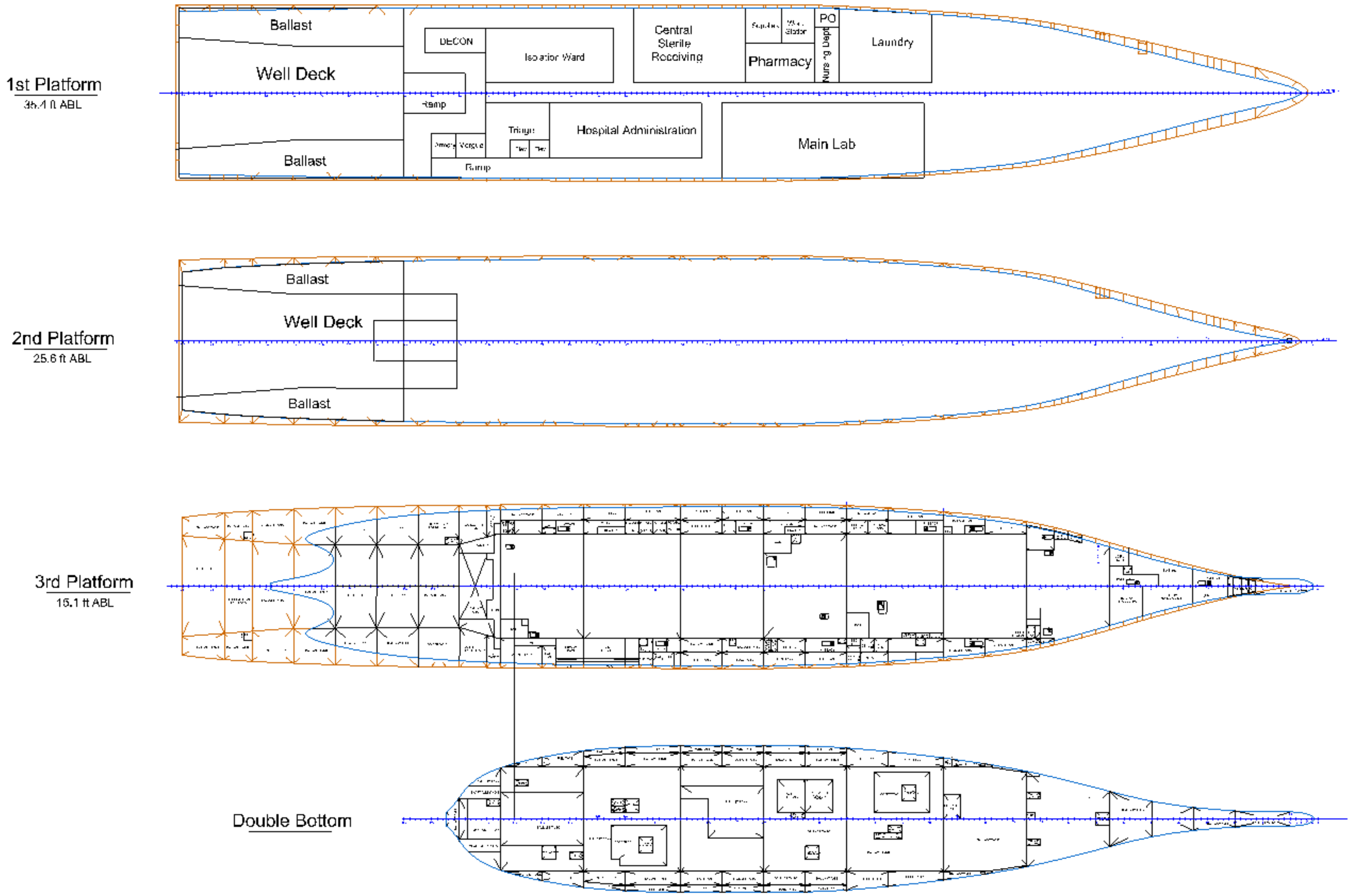
260	**Propul Fuel & Lube Oil**	**13.80**
261	Fuel Service System	13.60
264	Lube Oil Handling	1.00
300	**Electric Plant, General**	**763.90**
310	**Electric Power Generation**	**210.90**
311	Ship Service Power Gene	200.00
313	Batteries + Service Facilities	4.00
314	Power Conversion Equipment	6.90
330	**Lighting System**	**553.00**
400	**Command + Surveillance**	**658.10**
410	**Command + Control Sys**	**64.40**
411	Data Display Group	34.50
412	Data Processing Group	29.90
430	**Interior Communications**	**40.00**
440	**Exterior Communications**	**152.00**
441	Radio Systems	152.00
450	**Surf Surv Sys (Radar)**	**179.80**
451	Surface Search Radar	-
455	Identification Systems	-
456	Multiple Mode Radar	-
460	**Underwater Surveillance**	**55.00**
461	Active Sonar	55.00
466	Lamps Electronics	-
470	**Countermeasures**	**88.80**
472	Passive Ecm	-
473	Torpedo Decoys	-
474	Decoys (Other)	-
475	Degaussing	88.80
480	**Fire Control Sys**	**37.30**
481	Gun Fire Control System	-
482	Missile Fire Control Sy	37.30
483	Underwater Fire Control	-
484	Integrated Fire Control	-
490	**Special Purpose Sys**	**40.80**
491	Elctrnc Test,Chkout,Mon	6.40
493	Non-Combat Data Process	21.20
495	Spec Purpose Intelligen	-
500	**Auxiliary Systems**	**4,160.90**
510	**Climate Control**	**3,304.90**
511	Compartment Heating Sys	1,513.60
512	Ventilation System	871.10
514	Air Conditioning System	900.00
516	Refrigeration System	20.20
520	**Sea Water Systems**	**211.10**
521	Firemain + Sea Water Flus	211.10
529	Drainage + Ballasting Sys	2.00
530	**Fresh Water Systems**	**343.70**
531	Distilling Plant	67.10

532	Cooling Water	12.40
533	Potable Water	264.20
540	**Fuels/Lubricants,Handlin**	**69.80**
541	Ship Fuel + Compensating	47.30
542	Aviation + General Purpose	22.50
550	**Air,Gas + Misc Fluid Syste**	**48.80**
551	Compressed Air Systems	48.80
560	**Ship Cntl Sys**	**110.10**
561	Steering + Diving Cntl Sy	110.10
580	**Mechanical Handling Syst**	**36.20**
583	Boats,Handling + Stowage	16.00
584	Mech Oper Door,Gate,Ram	10.40
588	Aircraft Handling,Servi	9.80
590	**Special Purpose Systems**	**36.30**
593	Environmental Pollution	36.30
600	**Outfit + Furnishing,General**	**344.30**
620	**Hull Compartmentation**	**23.40**
625	Airports, Fixed Portligh	23.40
630	**Preservatives + Coverings**	**18.00**
633	Cathodic Protection	18.00
650	**Service Spaces**	**251.00**
651	Commissary Spaces	157.30
652	Medical Spaces	11.30
655	Laundry Spaces	79.10
656	Trash Disposal Spaces	3.20
660	**Working Spaces**	**51.90**
665	Workshops,Labs,Test Are	51.90
700	**Armament**	**118.50**
710	**Guns + Ammunition**	-
720	**Missiles + Rockets**	**10.30**
721	Launching Devices	10.30
750	**Torpedoes**	-
770	**Cargo Munitions**	**108.20**
772	Cargo Munitions Handling	108.20
	Total Loads	6,082.00

Appendix E: General Arrangements



Naval Surface Warfare Center Carderock Division
Center for Innovation in Ship Design
Hospital Ship Replacement



Appendix F: Wärtsilä Gensets (18V32)

WÄRTSILÄ GENSET 32

IMO Tier II

Main data

Cylinder bore ....320 mm
Piston stroke..............................400 mm
Cylinder output.................. 480, 500 kW/cyl
Engine speed...........................720, 750 rpm
Mean effective pressure ....24.9 bar
Piston speed.......................... 9.6, 10.0 m/s
Generator voltage.................. 0.4 – 13.8 kV
Generator efficiency .... 0.95 – 0.97

Fuel oil specification:
700 cSt/50°C
7200 sR1/100°F
ISO 8217, category ISO-F-RMK 700
SFOC 175 g/kWh
at ISO condition

Options: Common rail fuel injection,crude oil.

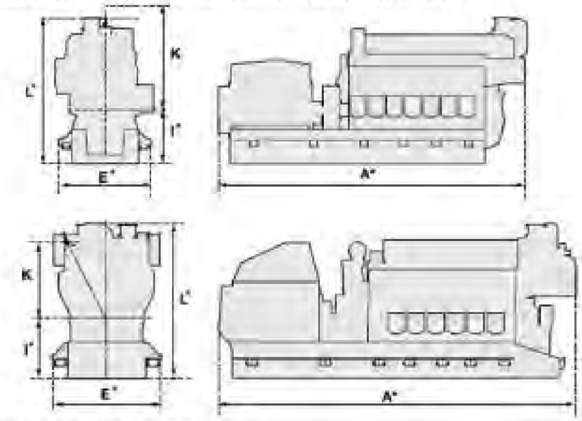
Rated power generating sets

Engine type	60 Hz/720 rpm				50 Hz/750 rpm			
	480 kW/cyl		550 kW/cyl		500 kW/cyl		580 kW/cyl	
	Engine kW	Gen. kW	Engine kW	Gen. kW	Engine kW	Gen. kW	Engine kW	Gen. kW
6L32	2 880	2 760	3300	3170	3 000	2 880	3480	3340
7L32	3 360	3 230	3850	3700	3 500	3 360	–	–
8L32	3 840	3 690	4400	4220	4 000	3 840	4640	4450
9L32	4 320	4 150	4950	4750	4 500	4 320	5220	5010
12V32	5 760	5 530	6600	6340	6 000	5 760	6960	6680
16V32	7 680	7 370	8800	8450	8 000	7 680	9280	8910
18V32	8 640	8 290	9900	9500	9 000	8 640	–	–

Dimensions (mm) and weights (tonnes)

Engine type	A*	E*	I*	K	L*	Weight*
6L32	8 345	2 290	1 450	2 345	3 940	57
7L32	9 215	2 690	1 650	2 345	4 140	69
8L32	9 755	2 690	1 630	2 345	3 925	77
9L32	10 475	2 890	1 630	2 345	3 925	84
12V32	10 075	3 060	1 700	2 120	4 385	96
16V32	11 175	3 060	1 850	2 120	4 280	121
18V32	11 825	3 360	1 850	2 120	4 280	133

* Dependent on generator type and size.
Generator output based on a generator efficiency of 96%.
Final measurements might differ depending on selected turbocharger execution



GENERATING SET DIMENSIONS

A Total length of the generating set.

E Total width of the generating set.

I Distance from the bottom of the common baseframe to the crankshaft centreline.

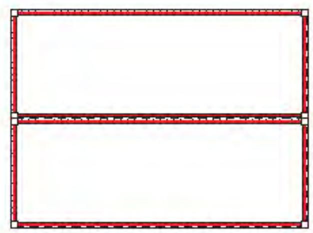
K Minimum height from the crankshaft centreline when removing a piston.

L Total height of the generating set.

Appendix G: KARBOX ISO Container: Operating Hall

Medical equipment	
Operational table	1
Surgeon´s chair	2
Operational single-arm lighting unit	1
Tripod	1
Anaesthesiological apparatus with monitor	1
Anaesthetist´s chair	1
Negatoscope	1
Electric extraction system - mobile	1
Infusion pump	2
Linear dosing machine	2
Laryngoscope	1
Heating underlay under patient	1
Defibrillator	1
AMBU bag	1
Cryomachine	1
Infusion support stand	1
X-RAY C arm	1
Hydraulic medical instrument table	1
Germicidal emitter - closed	8

Non-medical equipment	
Source pons	1
Distribution of medical gasses	1
Instrument table	2
Hydraulic medical instruments table	1
Compressor	1
Stainless washbasin	1
Soap dispense	1
Disinfecting fluid dispense	1
Closed waste bin	1
Special container for medical waste	1
Fire extinguisher	1



Ground plan of OPERATING HALL containers

OPERATING HALLS container dimensions

Container exterior dimensions

container lenght	6 058 mm
container width	4 876 mm
container height	2 438 mm

Container interior dimensions

lenght	5 804 mm
width	4 640 mm
height	2 075 mm

Maximum gross mass of 1 container	12 000 kg

Appendix H: OxyStar Oxygen Generation System

OXYSTAR99 standard features

The oxygen generator is constituted of the following elements :
- integral frame* including first production stage 95% and second production stage 99%
- pneumatic, electrical and monitoring parts
- 2 PSA sieve beds (Nitrogen) 2 PSA sieve beds (Argon)
- High definition touch screen control panel
- separate oxygen receiver with flexible hoses set
- 2 air inlet filters with manual drain valve (25 µm and 0.1 µm)
- 1 oxygen outlet filter with manual drain valve

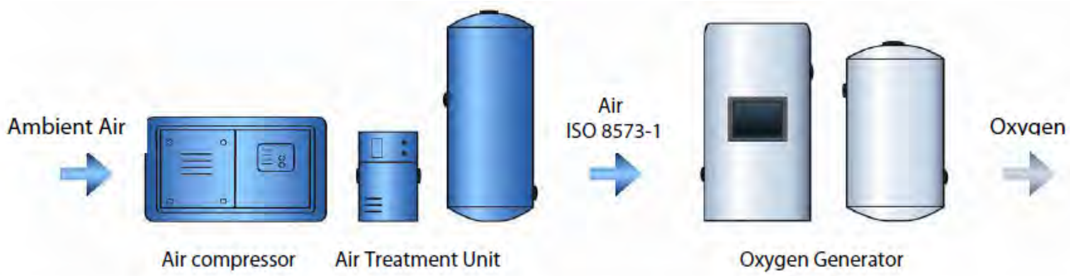
*except for OxyStar99 330 model

Technical data					
		OxyStar99 153	**OxyStar99 219**	**OxyStar99 300**	**OxyStar99 330**
Oxygen purity	*%*	98.8 to 99.2			
Maximum **oxygen flow at 99%** *	*Nm3/h*	**9.2**	**13.1**	**16**	**20**
Maximum oxygen flow at 99% *	*SCFH*	324.9	462.6	565	706.2
Oxygen outlet pressure		5 to 6 bar – 72 to 87 Psig			
Minimum requested O2 receiver capacity	*L*	500	1 000	1 000	1 000
Oxygen outlet diameter	*"G*	3/4	3/4	3/4	3/4
Air inlet diameter	*"G*	1"1/2	1"1/2	1"1/2	1"1/2
Dimensions (without O2 tank)	*L x w x h - cm*	130 x 75 x 160	130 x 75 x 160	130 x 75 x 160	155 x 95 x 220
Weight	*Kg*	465	515	750	1 520
Power supply *voltage – frequency – protection*		230 V 1ph – 50 Hz – 6 A			
Feed air requirements		Please refer to Feed Air Station technical datasheet			

* **Oxyplus oxygen generators** are specially designed **for hospital consumption profile**

Appendix I: OxyStar Feed Air System

The following feed air system works with the OxyStar$_{99}$330 system.



Feed Air Requirement					
Suitable for		**Premium 540 HF Oxystar$_{99}$219 Orlane 600**	**Premium 620 HF OxyStar$_{99}$ 300 Orlane 720**	**Premium 700 HF OxyStar$_{99}$ 330 Orlane 900**	**Premium 830 HF OxyStar$_{99}$ 415 Orlane 1 200**
Clean and dry Air	*In Compliance with*	ISO 8573-1			
Air compressor power	*KW*	37	45	55	75
Air flow rate	*Nm3/h*	315	378	492	630
Air flow rate	*SCFH*	11 124	13 349	17 375	22 248
Air compressed pressure		10 bar – 145 Psig			
Air receiver volume (minimum)	*L*	1 500	1500	1 500	2 000
Air treatment station capacity	*Nm3/h*	420	420	540	640
Air treatment station capacity	*SCFH*	14832	14 832	19 070	22 598.8
Dew point (maximum)	*°C*	3			
Air filtration – max. solid particles size	*µm*	25			
Air filtration – max. oil concentration	*mg/m3*	0.01			

Standard geographical and climatic conditions : Ambient temperature : + 5 °C to + 25 °C – Altitude : sea level – Relative humidity : 75 %. *For different geographical and climatic conditions, local conditions must be taken into account to size the Feed Air Station.*

Appendix J: SteriMed specifications

capacity (per cycle)

Bagged waste: 70 liters (18.5 gal.)
~ 14 kg (30 lbs.)
Sharps containers: (1) 5 gal. or (2) 2 gal.
Dialysis kits: ~ 10 single use or 16 reuse

consumption

Water: 38 liters (10 gal.) per cycle
Ster-Cid® disinfectant: 175 ml (.05 gal.) per cycle
Power: ~ 0.4 KWh

physical dimensions

Height: 155 cm (60")
Width: 183 cm (72")
Depth: 70 cm (27")
Weight: 750 kg (1650 lbs.)

utilities requirements

Electrical (US): 3 phase, 60 Hz,
480 VAC, 16 Amp or 240 VAC, 25 Amp
(International): 3 phase, 50 Hz,
400 VAC,16 Amp
Water supply: 19 mm (3/4") line,
250-550 Kpa (35-77 psi)
Floor drain: 110 mm (4") diameter

Ster-Cid® is a trademark of MCM Environmental Technologies, Inc.

Appendix K: SOLAS Approved Noreq Lifeboats

Type	Dimension [LxWxH]	Max Seating [p]	Hook Distance [m]	Davit Load [kg]
LBT 525 T	5.25 x 2.30 x 3.05	25	4.90	4,537
LBT 650 T	6.50 x 2.30 x 3.10	36	6.10	5,825
LBT 700 T	7.00 x 2.70 x 3.10	48	6.60	7,224
LBT 750 T	7.50 x 2.90 x 3.25	68	7.10	8,608
LBT 850 T	8.50 x 2.90 x 3.25	80	8.14	10,656
LBT 935 T	9.35 x 3.60 x 3.25	102	8.95	13,250
LBT 1090T	10.90 x 3.90 x 3.50	130	10.50	16,675

SOLAS approved Rescue Boats *(FRB 650 Twin 90 hp)*				
Type	**Dimension [LxWxH]**	**Capacity [p]**	**Speed [knots]**	**Davit Load [kg]**
FRB 610 [outboard 60 hp]	6.10 x 2.20 x 2.35	6	22	1,421
FRB 610 [outboard 90 hp]	6.10 x 2.20 x 2.35	6	25	1,487
FRB 650 Twin 60 hp	6.50 x 2.32 x 2.30	15	28	2,585
FRB 650 Twin 90 hp	6.50 x 2.32 x 2.30	15	34	2,735
FRB 650 [inboard 212 hp]	6.50 x 2.32 x 2.30	15	30	2,825
FRB 750 [inboard 212 hp]	7.50 x 2.32 x 2.30	15	30	2,945
Fast rescue boats in stock. See: www.noreq.no				

Appendix L: HSR Detailed Equipment List

Equipment	QTY	Indiv. Weight (LT)	Total Weight (LT)
Azipod XO1800	2	289.12	578.24
Aqua-Chem Watermaker	1	113.84	113.84
Wärtsilä Genset 16V32	4	523.60	2094.39
OxyPlus Oxystar99 300	2	0.74	1.48
CH-53K Helicopter	1	38.84	38.84
CATSCAN	1	3.19	3.19
X-Ray	1	0.21	0.21
MRI	4	11.8	47.2
Noreq Lifeboats LBT 1090 C	6	6.82	40.92
Noreq Lifeboats LBT 935 C	6	5.51	33.06
Noreq Lifeboats LBT 650 C	3	3.08	9.24
Noreq Fast Rescue Boat FRB 650 Twin 90 hp	2	2.69	5.38
Noreq Davits (36)	3	5.22	15.66
Mitsubishi FD160N Fork Lift	1	18.65	18.65
ISO Container (Fully Loaded)	6	11.81	70.86
MCM Technologies SteriMed	1	0.74	0.74
SAIC Solid Waste Shredder	1	0.58	0.58
SAIC Plastic Waste Shredder	1	0.58	0.58
SAIC Compress Melt Unit Mod 1	1	0.58	0.58
SAIC Large Pulper	1	1.25	1.25
Crawford CB35SW Incinerator	1	5.45	5.45
Bilge Water Treatment	1	0.67	0.67
Marine Sewage Treatment	2	7.87	15.74
Total	**48**	**1,041**	**3,050**

Appendix M: References

1. Blewett, William K., Harris, MSG Jef L., and Seitzinger, Alan T. *Receiving CBW-Contaminated Casualties Aboard a T-AH20 Hospital Ship – Phase I Report.* January 1996.
2. Burke, Darlene M. *The Hospital Ship: A Mixed Blessing for the Operational Commander*. Rep. Department of the Navy.
3. Carey, Neil, Grefer, James, Trost, Robert and Robert Levy. "Future Deployable Medical Capabilities and Platforms for Navy Medicine." CNA. February 2002.
4. Department of the Navy. *Accommodation Standards for Military Sealift Command Ships*. Tech. No. 9330.6D.
5. Hanthorn, LT Dave, Sewell, LT Eli, and Tepper, LT Nadia. "LPD-17 Hospital Ship Variant." Massachusetts Institute of Technology. January 30, 2009.
6. Jurkiewicz, David. *Use of Heavy Lift Ships as Modular Casualty Receiving Ships.* NSWCCD-CISD-2006/005. April 2007.
7. Mattonen, Maryann C. "The Use of Hospital Ships for Joint, Interagency, and Multinational Humanitarian Assistance Operations." Naval War College. February 13, 2006.
8. Negus, Tracy L., Carrie J. Brown, and Paula Konoske. "Military Medicine." *Determining Medical Staffing Requirements for Humanitarian Assistance Missions* 1st ser. 175.1 (2010): 1-6.
9. Reid, Alan R., Huff, David S., and John C. Cameron. "Conversion of *San Clemente* Class Tankers to Hospital Ships for the U.S. Navy." *Marine Technology*. Vol. 24 (July 1987): 193-20.
10. Salenga, Edilberto M. "Developing Soft Power Using Afloat Medical Capabilities." U.S. Army War College. 2-03-2009.
11. Wang, Daniel, Grecer, Onur, Gougoulidis, George, Gold, Robert. "Crisis Response Vehicle (CRV) Conversion Study." 13.413 --- Projects in Naval Ships Conversion Design. MIT. 25 February 2003.
12. Michelis, Alexandros, Smith, Matthew, and Summers, Simon. "Initial Capabilities Document – Conversion of Dock Landing Ship (LSD)-41 Class Vessel to Hospital Ship with Naval Construction Force Capability." January 8, 2008.